This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

EOLOGICAL SURVEY

No. 77

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE TEXAN PERMIAN

AND ITS

MESOZOIC TYPES OF FOSSILS

BY

CHARLES A. WHITE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE TEXAN PERMIAN

AND ITS

MESOZOIC TYPES OF FOSSILS

BY

CHARLES A. WHITE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

CONTENTS.

	Page.
Letter of transmittal	7
Synopsis of results	8
Introduction	9
Description of species	19
General discussion	30
Index	51

ILLUSTRATIONS.

	Page.
PLATE I. Waagenoceras cumminsi, Popanoceras walcotti, Medlicottia copei	44
PLATE II. Goniatites baylorensis, Nautilus occidentalis, Nautilus (Endolobus) ——?, Nautilus ——?, Nautilus ——?, Orthoceras rushensis	46
PLATE III. Nautilus winslowi, Nautilus ——?, Euomphalus subquadratus, Naticopsis remex, Naticopsis shumardi, Bellerophon montfortianus, Patella ——?, Murchisonia ——?, Spirorbis——?	48
PLATE IV. Aviculopecten occidentalis, Gervillia longa, Clidophorus occidentalis, Yoldia? subscitula, Pleurophorus ——?, Sedgwickia topekaensis, Myalina aviculoides, M. perattenuata, M. permiana, Cythere nebrascensis	50
FIG. 1. Horizontal section from the eastern part of Navarro County to Swisher County, Texas	14

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF MESOZOIC INVERTEBRATES,
Washington, D. C., November 21, 1890.

SIR: I herewith transmit manuscript and drawings for a bulletin of the Survey. A noteworthy feature of this brief memoir is the announcement of the commingling in one and the same stratum of fossil forms such as usually have been regarded as characteristic of Mesozoic strata with those which have been regarded as equally characteristic of Paleozoic strata.

The facts herein recorded indicate that extreme caution ought to be used in assigning certain formations to a predetermined geological horizon, especially those which lie upon the confines of recognized systems. They also suggest that some revision of former conclusions as to the true geological age of certain North American formations may be necessary.

Very respectfully,

C. A. WHITE,
Geologist in charge.

Hon. J. W. POWELL,
Director.

SYNOPSIS OF RESULTS.

In this bulletin is presented a summary of the various kinds of evidence that properly may be accepted as indicating the Permian age of a certain series of strata in western Texas, which have been by some geologists referred to the Trias, and by others to the Permian.

It also contains an announcement of the discovery in those strata of certain types of invertebrate fossils which usually are regarded as indicative of their Mesozoic age, commingled with a considerable number of Carboniferous types. A large proportion of the latter forms are well known Coal-Measure species.

All these species are illustrated on accompanying plates, and some of them are described as new. This discovery is the first of the kind that has been published concerning North American strata, but it is similar in character to those made by Waagen in India, Gemmellaro in Sicily, and Karpinsky in Russia.

The paleontological balance which is indicated by this commingling of earlier and later types in the Texan strata is treated as an item of evidence in favor of their Permian age.

The closing portion of the bulletin is devoted to a general discussion of the subject of the existence of the Permian in North America.

THE TEXAN PERMIAN AND ITS MESOZOIC TYPES OF FOSSILS.

By Charles A. White.

INTRODUCTION.

In the autumn of 1887, Mr. W. F. Cummins, Assistant State Geologist of Texas, placed in my hands a small suite of fossil shells which he had collected in Baylor and Archer Counties, in northern Texas, from the strata which furnished the large Permian vertebrate fauna that has been published by Prof. E. D. Cope.[1] A part of these shells I recognized as belonging to well known Coal-Measure[2] species; but among them were some unpublished forms which belong to types that strongly suggest their Mesozoic age. Mr. Cummins nevertheless assured me that they all came from the strata just mentioned, and that all the Mesozoic forms were found commingled in one and the same stratum with the greater part of the Coal-Measure species referred to. Although I had no reason to doubt either Mr. Cummins's statement or the accuracy of his observation, I was gratified upon beginning their study to find among the fossils themselves satisfactory evidence that they were really commingled in one and the same stratum. That is, upon examining the specimens under a lens I found the stony matrix of all of them to be of the same character, and I also discovered in the material adhering to them and filling their cavities numerous shells of a small ostracoid crustacean, which in this bulletin is referred to the *Cythere nebrascensis* of Geinitz, and which evidently formed a part of the same fauna as the mollusca with whose shells they were found associated.

The world has become familiar with Prof. W. Waagen's great discovery in the strata of the Salt Range in India of numerous molluscan forms of Mesozoic type commingled with a characteristic Carboniferous fauna;[3] and about two years ago Prof. G. G. Gemmellaro published

[1] See Systematic Catalogue of the Permian Vertebrate Fauna of North America. Trans. Am. Philos. Soc. 1888, vol. 16, pp. 285–288.

[2] The term Coal Measures is now often applied to the Mesozoic coal-bearing strata of western North America, but it is the middle division of the Carboniferous system that is here referred to.

[3] See Mem. Geol. Surv., India; Paleont. Indica, ser. XIII, Salt Range Fossils.

results of a similar discovery in Sicily, which evidently rivals that of India.[1]

The small collection of fossils which was obtained by Mr. Cummins seemed to indicate that we have in the upper part of the Carboniferous system in North America a commingling of Mesozoic and Paleozoic forms similar to that which has been discovered in India and in Sicily. The importance of such a discovery on this continent was so obvious that I decided to visit the locality from which the fossils were obtained and to make observations in person before publishing the discovery. Therefore, in the autumn of 1888, in company with Mr. Cummins, I examined a considerable part of the region in which the formation occurs and made important additions to the fossil collections which were before obtained. The principal results of that examination, together with other relevant matter, are recorded in this bulletin.[2]

The formation from which these Texan fossils were collected is the one which, upon the geological map compiled from previously published works by Mr. W. J. McGee,[3] as well as the one by Prof. C. H. Hitchcock,[4] is represented as Triassic; but, so far as I am aware, it has never been claimed by those who have so referred it that any Triassic fossils have been found in it. It is also the same formation that has for a number of years been referred to the Permian by Prof. Cope, who claims that its vertebrate fauna fully warrants such a reference. Although composed of ordinary sedimentary strata it is a copper-bearing formation, certain layers of it having long been known to contain considerable quantities of copper ore in the form of nodules and small xyloid masses. The former are composed of chalcocite, coated with a film of malachite, and the latter of melaconite, combined with which is some chloride of copper.[5]

A large part of the vertebrate fossils which Prof. Cope has published

[1] See Giornale di Sci. Nat. ed Econom., vol. 19, 1888. La Fauna dei Calcari con Fusulina della Valle del Fiume Sosio nella Provincia di Palermo: per Gaetano Giorgio Gemmellaro; pp. 2-106, Tav. A and I-X. After the manuscript of this bulletin had gone to the printer I received two important publications of a character similar to that of those which have just been referred to. The first is by Mr. A. Karpinsky, concerning certain Carboniferous strata in Russia. See Ueber die Ammoneen der Artinskstufe, etc., Mém. l'Acad. Imp. Sci. de St. Pétersbourg, VII[e] serie, tome 37, No. 2. The other is the second publication of Prof. G. G. Gemmellaro concerning the fauna of the Fusulina limestone of Sicily. See I Crostacei dei calcari con Fusulina della valle del fiume Sosio, vol. 8, series 3, No. 1, Mem. Soc. Italiana delle Scienze.

[2] Soon after this Texan discovery was made I published an article concerning it, with descriptions of some of its fossils, in the American Naturalist, vol. 23, pp. 109-128. Professor Gemmellaro's work had not then reached me, which accounts for the fact that it was not noticed in that article.

[3] See Fifth Annual Report Director U. S. Geological Survey.

[4] See Geol. Map U. S. and part of Canada; compiled by C. H. Hitchcock for the Amer. Inst. Mining Engineers, 1886.

[5] These qualitative determinations were made by Mr. W. S. Yeates, of the U. S. National Museum. The ores are found in Archer, and several other contiguous counties of Texas, and occur in friable sandy and clayey layers among strata which, unlike the Kupferschiefer of Germany, contain very little carbonaceous matter. They are not found in either true or gash veins, but the small masses of nearly pure ore are sporadically distributed in the soft, unaltered sedimentary layers of that part of the Texan Permian which is represented by No. 4 of the descriptive section, on page 15. Some years ago two companies were formed to mine these ores, but both of them soon suspended operations because they were unprofitable.

from this formation were collected by Mr. Cummins who, in making those collections and in other ways, has gained much information as to its character and extent in Texas and the Indian Territory. As my own observations have extended over only a part of the area which the formation is known to occupy in Texas, the following statements concerning its boundaries and extent are based mainly upon information derived from him.

In Texas this formation occupies an area many hundred square miles in extent, which constitutes the western part of the southern extension of the great central Paleozoic region of the continent. The southern boundary of this area is not now definitely known, but it lies at least as far south as the Concho River. Its eastern boundary may be approximately designated as extending from Red River to the Colorado through Clay, Young, Shackelford, Callahan and Runnels Counties; and its western border as extending from the Canadian River to the Concho through Hemphill, Wheeler, Donley, Briscoe, Motley, Dickens, Garza, Borden and Howard Counties. The formation is known to extend far within the Indian Territory, but in this bulletin special reference is made only to that portion of it which is found in Texas; and the description which is herein given is mainly drawn from observations made in Baylor, Archer, and other contiguous counties.

The strata in question rest directly and conformably upon another series in which a characteristic fauna of the Coal-Measure period prevails, but this Coal-Measure fauna is now not known to include any fossils of Mesozoic types, if we except the *Ammonites parkeri* of Heilprin, which he states was obtained from the Carboniferous rocks in Wise County.[1]

Notwithstanding the Mesozoic character of a part of the molluscan fauna of the upper strata the preponderance of evidence makes it necessary to regard it as belonging to the great Carboniferous system and as constituting an upper member of it. For these and other reasons yet to be stated I think this Texan formation may properly receive the designation of Permian which Prof. Cope has already applied to it, but I shall briefly discuss in the following paragraphs the propriety of using that name for at least the greater part of the North American strata to which it has been applied.

The Texan Permian, while not contrasting strongly with the Coal-Measure formation which underlies it, is readily distinguishable from it by general aspect and lithological character; and yet the Permian strata blend so gradually with those of the underlying Coal Measures and with the overlying gypsum-bearing beds, which are presently to be noticed, that it is difficult to designate a plane of demarkation in either case.

The Permian strata consist of materials which are somewhat difficult to characterize, but in a general way they may be described as consist-

[1] See Proc. Acad. Nat. Sci. Philad. 1884, vol. 36, pp. 53-55.

ing mainly of sandstones and sandy and clayey shales, which are sometimes calcareous, with here and there a few layers of impure limestone besides one somewhat persistent limestone horizon which has been observed in Baylor and Archer Counties. A common characteristic of many of the layers is the presence of an abundance of small, hard, rough concretions which usually become separated and accumulate upon weathered surfaces as the imbedding clayey material is removed by erosion, when they often present the appearance of a disintegrated coarse conglomerate. The observer is impressed with the prevailing reddish color of the whole formation, and during the rainy season the waters of the streams which traverse it are reddened by the abundant ferruginous clayey sediment which they receive as a product of erosion. This circumstance has given origin to the names of Red and Colorado Rivers, both of which traverse the Texan Permian.

The stratification is generally more or less regular, but in the district here specially referred to the formation contains comparatively few compact, evenly bedded strata. Because of this, and also because the strata have in this district been only slightly disturbed since their deposition, few striking features in the landscape occur. That is, the district is comparatively a plain country, the surface of which, in the general absence of forests, is diversified only by shallow valleys of erosion and low hills of circumdenudation, with here and there a hill or bluff of like origin which reaches a height of one or two hundred feet above the general level. From the top of these higher elevations extended landscape views may be obtained, which are of much advantage in the study of geological structure in that region.

Because of the slight disturbance which the Permian strata have suffered in the district referred to, and the general absence of bold escarpments, it is difficult to arrive at an accurate measurement of the thickness of the formation, but it is estimated at 1,000 feet. By distant view from the hills before mentioned, a general dip of the whole formation toward the west is plainly discernible. It is from a succession of such observations of the dip, together with measurements of the thickness of exposed strata and estimates of that of the unexposed, that the foregoing estimate of the thickness of the formation has been made.

A list of all the species of invertebrate fossils that have been discovered in the Texan Permian is given on a following page. A full list of the vertebrate species from the same formation has been published by Prof. Cope,[1] but no determinations of its fossil plants have yet been made known. Prof. Cope's list comprises 10 species of fishes, 11 of batrachians, and 33 of reptiles; making 54 species in all.

The full thickness of the Coal-Measure series in Texas is not yet known, its base not having been observed; but the portion that has been examined reaches an estimated thickness of 1,800 feet. The strata

[1] See Trans. Am. Philos. Soc. 1888, vol. 16, pp. 285-288.

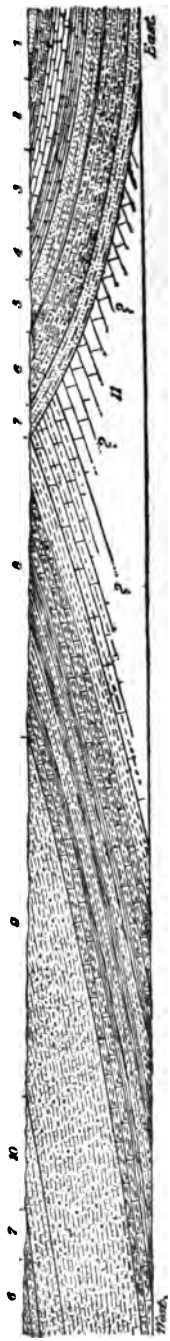
are generally somewhat evenly bedded and consist of bluish and gray limestones, gray and ferruginous sandstones, bluish and dark carbonaceous shales and clays; and several coal horizons are now known to exist there.[1] These strata have furnished at numerous localities and in greater or less abundance such characteristic Coal-Measure invertebrates as the following: *Terebratula bovidens* Morton, *Spirifer cameratus* Morton, *Athyris subtilita* Hall, *Productus cora* d'Orb., *P. nebrascensis* Owen, *P. costatus* Sowerby, *P. semireticulatus* Martin, *Hemipronites crassus* Meek & Hayden, *Myalina subquadrata* Shumard, *Allorisma subcuneata* M. & H., *Nuculana bellistriata* Stevens, *Pleurotomaria tabulata* Conrad, *Bellerophon carbonarius* Cox, *B. percarinatus* Conrad, and *Macrocheilus ponderosus* Swallow. Many other species have also been found associated with those which have just been named, but the latter are quite sufficient to characterize the strata containing them as belonging to the Coal-Measure series.

Along the western boundary of the Texan Permian, as it has been characterized in preceding paragraphs, a series of strata, about 250 feet in maximum thickness, now generally known as the gypsum-bearing beds and thought by some geologists to be of Triassic age, rests conformably upon the Permian. In general aspect, in a prevailing reddish color, and in general lithological character, except in the prevalence of gypsum in many of the layers, and the somewhat greater prevalence of clayey material, these overlying beds resemble the Permian strata upon which they rest. With only one known exception, these gypsum-bearing beds have furnished no fossils. The exception referred to is the discovery by Mr. Cummins in Hardeman County, in an upper stratum of those beds, of a thin magnesian layer containing numerous casts of a species of *Pleurophorus*. This being generally regarded as a characteristic genus among Permian molluscan faunas, and also being a prevailing form in the Permian strata beneath these gypsum-bearing beds, the question is suggested whether the latter ought not to be regarded as constituting an upper part of the Texan Permian. These beds have yet furnished no fossils which can with propriety be referred to the Trias, and it is questionable whether any Triassic strata exist in Texas.

It will be seen from the foregoing remarks that there is in the part of northern Texas to which special reference has been made a great conformable series of strata which has a gentle general dip toward the west, and which includes the strata that in this bulletin are referred to the Permian. It is overlain only by the débris resulting from its own disintegration except along the eastern and western bordersof the region which it occupies, where Cretaceous formations lap upon it. This overlapping conceals its base, but the estimated thickness of the whole series, so far as it is exposed to view, is 3,050 feet. The lower 1,800 feet, together with an unknown thickness beneath, is referred to the Coal Measures. The next overlying 1,000 feet of strata are referred to

[1] Mr. Cummins informs me in a letter that he has distinguished no less than nine coal horizons.

the Permian; and the upper 250 feet of the whole series, commonly known as the gypsum-bearing beds, probably constitute the upper part of the Permian.



The Cretaceous strata referred to rest unconformably and with a contrary dip upon the earlier, eastern portion of the whole series, while upon the later, western portion of it they rest with apparent conformity, although their real conformity may well be questioned because the Jura seems to be entirely wanting there.

The relation of the parts of this great series to one another and their relation to later formations is illustrated by the accompanying section, Fig. 1. The dips are, of course, exaggerated in the figure by the difference between its horizontal and vertical scales.

FIG. 1.—*Horizontal section from the eastern part of Navarro County to Swisher County, Texas.*

1. Lignitic Beds.....Tertiary.
2. Ripley Formation.....Cretaceous.
3. Austin Formation.....Cretaceous.
4. Eagle Ford Formation.....Cretaceous.
5. Timber Creek Formation.....Cretaceous.
6. Comanche Series.....Cretaceous.
7. Trinity Formation[1].....Cretaceous?
8. Coal Measures.....Paleozoic.
9. Permian.....Paleozoic.
10. Gypsum-bearing Beds.....Paleozoic?

As already stated and illustrated by the accompanying figure, the Cretaceous strata appear to rest conformably upon the gypsum-bearing beds at the western end of the section, and the latter beds lie quite conformably with the Permian and Coal Measures beneath, all having a westward dip. On the contrary, in the district embracing the eastern end of the section, all the overlying formations from the Trinity to the Eocene, inclusive, have an easterly dip and seem to lie unconformably with the Coal Measures and Permian. For want of positive evidence upon this point, however, it is not certain that the Coal-Measure and Permian strata do not finally dip toward the east beneath the Cretaceous formations, forming there an anticlinal axis.

Having shown the stratigraphical relation of the Texan Permian with other formations in the same region, the former only need be further considered. The following descriptive section of those strata is taken from Mr. Cummins's field notes, but it has been in large part verified by my own personal observations. The different members of the section, which are indicated

[1] The name Dinosaur Sands was formerly used for this formation. See Proc. Acad. Nat. Sci. Phila., 1887, pp. 39-47.

by consecutive numbers, are not distinctly definable from one another, but the section is presented in this form for convenience in referring to the respective horizons at which collections of fossils have been made.

Descriptive section of the Texan Permian.

1. Reddish and mottled sandy clays with layers of sandstone.
2. Variously colored clayey and sandy concretionary strata with a few irregular layers of impure concretionary limestone, a stratum of grayish blue limestone being usually observable near the middle of the member in Baylor and Archer Counties.
3. Sandstones, alternating with clayey and sandy concretionary layers, and with a few fine-grained, siliceous layers.
4. Reddish and buff colored clayey and sandy shales with occasional layers of sandstone.
5. Sandstones and sandy shales with beds of reddish sandy clays, passing gradually into the Coal Measures beneath.

The vertebrate remains, which by their faunal characteristics Prof. Cope confidently refers to the Permian, occur at numerous localities and at many horizons from the base to the top of the section; but invertebrate remains have hitherto been discovered only in strata which are included in numbers 2 and 3 of that section. The lowermost known horizon at which invertebrates occur is about 400 feet above the base of the series, and the uppermost is about as much below the top of the same; that is, the invertebrate fossils described and figured in this bulletin come from the middle 200 feet in thickness of the Permian series as it has just been defined.

The localities at which these fossils were obtained, only three in number, are in Baylor and Archer Counties, and as the greater part of the district is still unsettled, they can be designated only in an indefinite way. The first of these localities, which is in the northwestern corner of Archer County, will be designated as "Camp Creek." The second one is in Baylor County, near the middle of its eastern boundary line, and will be designated as "Godwin Creek." The third is in the northeastern part of Baylor County, near where the now unused military road, constructed by General Earl Van Dorn, crossed the Big Wichita River. This locality is by the settlers of that region called the "Old Military Crossing," but it will in this bulletin be designated as the Military Crossing of the Big Wichita, or simply as the Military Crossing. The strata of the two first mentioned localities occur in No. 3 of the foregoing descriptive section of the Permian, and those of the last named one in No. 2 of the same.

The following is a list of all the invertebrate species which are now known to have been found in the Texan Permian, all of which are discussed on succeeding pages and illustrated on the accompanying plates. The list is presented in tabular form for the purpose of giving a synoptical view of the invertebrate fauna so far as it is at present known, and also to indicate the localities at which the respective species have been discovered, as well as their interassociation there.

As to the latter condition, it is proper to state that specimens of all the species found at the locality which is indicated at the head of the following list as the "military crossing" were collected by myself from a single stratum, where they were so commingled as to leave no room for doubt that they were all members of one and the same fauna, nor any that they all lived contemporaneously. Specimens of the greater part of the other species were also collected by me at the localities indicated. When not collected by myself the fact will be mentioned in connection with remarks upon the respective species.

List of invertebrate species from the Texan Permian.

	Camp Creek.	Godwin Creek.	Military Crossing.
1. Goniatites baylorensis n. s			×
2. Waagenoceras cumminsi White			×
3. Medlicottia copei W			×
4. Popanoceras walcotti W			×
5. Orthoceras rushensis McChesney?			×
6. Nautilus winslowi Meek & Worthen			×
7. N. occidentalis Swallow			×
8. N. ——?			×
9. N. ——?		×	
10. N. ——?			×
11. N. (Endolobus) ——?			×
12. Naticopsis remex W		×	×
13. N. shumardi McChesney?		×	
14. Enomphalus subquadratus M. & W			×
15. E ——?			×
16. Murchisonia ——?		×	×
17. Patella ——?		×	
18. Bellerophon crassus M. & W		×	×
19. B. montfortianus Norwood & Pratten		×	
20. B. ——?			×
21. Sedgwickia topekaensis Shumard sp		×	
22. Pleurophorus ——?		×	
23. Clidophorus occidentalis Geinitz		×	
24. Yoldia? subscitula Meek & Hayden		×	
25. Myalina permiana Swallow	×	×	×
26. M. aviculoides M. & H		×	
27. M. perattenuata M & H	×	×	×
28. Gervillia longa Geinitz		×	
29. Aviculopecten occidentalis Shumard			×
30. Syringopora ——?	×	×	
31. Spirorbis ——?			×
32. Cythere nebrascensis Geinitz			×

SUMMARY.

		Species.
Mollusca	Cephalopoda	11
	Gasteropoda	9
	Conchifera	9
Articulata	Vermes	1
	Crustacea	1
Radiata	Polypi	1
Total		32

By reference to the foregoing list of species, and especially to the summary at the end of the list, it will be seen that the invertebrate

collections which have hitherto been made from the Texan Permian do not represent a fauna in its usual proportions, either as regards the classes and families to which the species of the list respectively belong, or as regards the classes and families which are usually expected to be represented in a Permian fauna. This is especially true when we compare these collections with Permian faunas already known in other regions. For example, it will be seen that the Cephalopoda are in unusually large proportion, that the Brachiopoda and Polyzoa are absent, and that the Polypi are represented by only a single species. In short, it is plain that the invertebrate fauna which existed during the period in which the Texan Permian was deposited, and in the same or in contiguous waters, is imperfectly and disproportionately represented by these collections.

Some of the causes of the imperfection and disproportion referred to are too plainly apparent to need comment, and others are suggested by the lithological and stratigraphical character of the formation in which the remains are found. Besides the inevitable causes of imperfect representation of extinct faunas by their remains, a conspicuous reason for the imperfection of these collections is that the formation has yet been carefully examined in only a small part of the large region which it is known to occupy, and exhaustive search for invertebrate fossils has yet been made at only a few of the localities which have been visited by competent collectors.

Again, there are few strata entering into the composition of the Texan Permian, where it has been examined, the character of which indicates that they successively formed the bottom of waters where a large proportion of then existing invertebrates could have found a congenial habitat. That is, sandy and other siliceous strata, as has already been shown, prevail in this formation, while calcareous strata are comparatively rare. It is true that certain families, especially of the mollusca, find a siliceous, sandy bottom, such as most of those strata doubtless formed, more congenial than a muddy or a calcareous one; but to far the greater part of such invertebrate faunas the latter kind of bottom, other conditions being favorable, is much the more congenial. In short, the lithological character of a formation often presents an obvious reason, not only for the comparative paucity of all invertebrate fossils in its strata, but even for the absence of representatives of certain families which we have every reason to suppose existed contemporaneously in other, not far distant, places and in more congenial waters.

But these collections, imperfect as they are, present subjects for consideration which are of far greater interest than that which attaches to a mere addition to our knowledge of a few of the forms which constituted the fauna of any given epoch or period, such, for example, as the relation which the fauna of one period in a given region bore to faunas which were presumably contemporaneous with it, and to those of the periods which immediately preceded and followed it, and the

indication which these fossils give as to the geological age of the strata containing them.

For the purpose of presenting the latter subject as conspicuously as possible all the invertebrate forms which have hitherto been discovered in the Texan Permian, whether new or already published, will be discussed on the immediately following pages and figured on the accompanying plates.

DESCRIPTION OF SPECIES.

MOLLUSCA.

CEPHALOPODA.

Genus GONIATITES de Hahn.

GONIATITES BAYLORENSIS sp. nov.

Pl. II, Figs. 1–3.

Shell apparently reaching a moderately large size; its transverse diameter less than that of the plane of its coil; volutions moderately embracing; the peripheral and lateral portions regularly rounded from the border of one umbilicus to that of the other; umbilici deep and somewhat narrow, but showing a portion of each of the inner volutions, their borders abruptly rounded inward from the sides; the transverse diameter of the volutions nearly three times as great as the dorso-ventral diameter, a transverse section of them showing a lunate outline. Living chamber and aperture unknown. Septa moderately distant from one another; dorsal lobe longer than wide, deeply divided into two narrow, lanceolate, slightly diverging branches; dorsal and superior lateral saddles linguiform and nearly equal in size; the two saddles separated by the superior lateral lobe, which is simple, slightly constricted at the middle, and acutely pointed; the inferior lateral lobe similar in shape to the superior, but a little shorter, and less distinctly constricted; inferior lateral saddle a little shorter than the others, somewhat irregular in shape, and occupying the margin of the umbilicus. Surface apparently unornamented.

The only specimen in the collection, when perfect, probably reached a diameter of coil of about 55 millimetres.

This species bears considerable resemblance to the *G. globulosus* of Meek & Worthen, but the septa of the Texan form have each one more lobe and saddle between the periphery and the margin of the umbilicus than have those of the other form.

Locality: Military Crossing of the Big Wichita, Baylor County, Texas.

Genus WAAGENOCERAS Gemmellaro.

WAAGENOCERAS CUMMINSI White.

Pl. I, Figs. 4–8.

Ptychites cumminsi White, Am. Naturalist, 1889, vol. 23, p. 117, Pl. I, Figs. 4–8.
Compare with *Waagenoceras stachei*, Gemm. Gior. Sci. Nat. ed. Econ., vol. 19, 1888, p. 11, Pl. I, Figs. 4–6, and Pl. II, Figs. 3–4.

Shell compressed subglobose, transversely rounded on the periphery, and more broadly rounded on the sides; transverse constrictions appearing at irregular intervals upon casts of the interior of the shell; volutions so deeply embracing as to form small, narrow umbilici, the borders of which are narrowly rounded inward from the sides, and which show a small portion of each of the inner volutions; transverse section of the outer volution deeply crescentic. Surface apparently plain, but upon the border of the umbilicus in a couple of specimens fine revolving lines appear. Septa numerous and complex. The siphonal lobe large, deeply divided into two strongly digitate branches. The first lateral lobe is a little larger than a single branch of the siphonal lobe, but it is similarly digitate. The second and third lateral lobes are visible before the suture reaches the umbilicus, toward which the three lobes gradually decrease in size and complexity. Living chamber and aperture unknown.

The largest example in the collection indicates that it reached a diameter in the plane of the coil not less than 50 millimetres, but the living chamber is not shown in any of them. The figures on Pl. I of this bulletin are all of natural size. Those given in the American Naturalist are (loc. cit.) a little less.

Specimens representing about 40 individuals were found at the Military Crossing locality, all of which are imperfect, but the species has not yet been elsewhere discovered. The greater part of these specimens were collected by myself, and they were found in such association with the other species there as to leave no doubt that they were all members of one and the same fauna.

When I published this species in the American Naturalist (loc. cit.) I referred it to *Ptychites Mojsisovics*, Prof. Gemmellaro's work (op. cit.) not having then reached me. Upon comparing it with his description and figures it was plain that the Texan and Sicilian forms are congeneric. It is also plain that *Waagenoceras cumminsi* and *W. stachei* are closely related species.

Genus MEDLICOTTIA Waagen.

MEDLICOTTIA COPEI White.

Plate I, Figs. 1–3.

Medlicottia copei White, Am. Naturalist, 1889, vol. 23, p. 117, Pl. I, Figs, 1–3.

Shell thinly discoid, the sides gently convex; periphery narrow, having a moderately deep median groove; volutions so deeply embracing that only a small part of each of the inner ones is seen in the very narrow umbilici. Siphonal lobe long and slender, occupying the bottom of the peripheral groove, each side bearing four or five small indentations. External saddle very long and irregular in shape, in part occupying the ridge which borders each side of the peripheral groove, and in part overlain by the corresponding part of the next preceding external saddle. Five or six small denticles of nearly equal size are observable upon the side of the saddle within the peripheral groove, and seven or eight denticles of unequal length are seen upon the outer side. The other saddles are plain, linguiform or sublanceolate. The external lobe is stronger than any of the others, having two bifid branches, one directed backward in the curved line of the shell coil, and the other extending toward the periphery into the external saddle. The other lobes gradually diminish in size toward the umbilicus, most of which are bifid at the extremity; but the latter character does not appear upon small lobes of the inner portion of the volutions.

The largest example in the collection indicates a diameter of 60 millimetres; but as no trace of the living chamber is present, its full size is not known. The figures on Pl. I of this bulletin are of natural size. Those in the American Naturalist (loc. cit.) are a little less.

Three or four imperfect examples of this species were found at the Military Crossing locality, and one other near San Angelo, Tom Greene County, Texas. The latter locality is fully 150 miles from the former, which shows that the species had a considerable geographical distribution. This appears to be the only species of *Medlicottia* that has yet been found in North America, if we except an unpublished form from the Meekoceras beds of Idaho, which will doubtless fall either into this genus or Sageceras.

Genus POPANOCERAS Hyatt.

POPANOCERAS WALCOTTI White.

Pl. I, Figs. 9–11.

Popanoceras walcotti White, Am. Naturalist, 1889, vol. 23, p. 117, Pl. I, Figs. 9–11.
Compare with *Popanoceras multistriatum* Gemmellaro; Gior. Sci. Nat. ed. Econ. 1888, vol. XIX, p. 19, Pl. III, Figs. 1–5.

Shell discoid, periphery rounded; sides gently convex, the inner volutions almost wholly embraced by the next preceding one, and the

umbilici are consequently minute. Surface marked with numerous slightly raised and slightly sinuous radiating ridges, apparently indicating stages of growth, which extend continuously from one umbilicus to the other across the periphery. Septa, showing numerous short lobes and saddles, the former being simple and regularly rounded at the end, and the latter more or less notched or pointed at the extremity. Those near the periphery have sometimes three digitations, and those near the umbilicus are simple and more or less pointed. In full-grown examples the saddles are probably still more digitate.

Only one example of this species is known, which was found at the Military Crossing locality. The diameter of its coil is about 26 millimetres, all being occupied by the septa. The living chamber and aperture are therefore unknown. The figures given on Pl. I of this bulletin are of natural size; those given in the American Naturalist (loc. cit.) are a little less.

The close specific relationship of *Waagenoceras cumminsi* with *W. stachei* has been mentioned, and by comparing *Popanoceras walcotti* with *P. multistriatum* it will be seen that these two species are also closely related in all their observable characteristics, both suggesting a close relationship of the Texan and Sicilian faunas.

Genus ORTHOCERAS Breynius.

ORTHOCERAS RUSHENSIS McChesney?

Pl. II, Figs. 14–16.

Orthoceras rushensis McChesney, 1859, New Paleozoic Fossils, p. 68.
Compare with *Orthoceras* sp. undet. Meek & Worthen, Geol. Survey Illinois, 1873, vol. 5, Pl. XXX, Fig. 5.

The collection from the Military Crossing of the Big Wichita contains numerous fragments of shells belonging to the genus *Orthoceras*, which possibly represent more than one species, but much the greater part of them evidently belong to one and the same. Shells of this genus usually present too few salient characters for satisfactory specific discrimination, and this is especially the case with the fragmentary specimens of the collection now in hand. The external shell is present upon some of the specimens, but the surface shows none of the markings which characterize the *O. cribrosum* of Geinitz from Nebraska City. I have therefore referred the Texan form to McChesney's species, the type specimens of which were obtained from the Coal Measures of Indiana and Illinois.

Genus NAUTILUS Breynius.

NAUTILUS (TEMNOCHEILUS) WINSLOWI Meek & Worthen.

Pl. III, Figs. 1–5.

Nautilus (*Temnocheilus*) *winslowi* M. & W. Geol. Survey, Illinois, 1873, vol. 5, p. 609, Pl. XXXII, Fig. 2.
Compare with *N.* (*T.*) *latus* M. & W., ib., p. 608, Pl. XX, Fig. 2.

A considerable number of imperfect specimens and fragments of a species of *Nautilus* occur among the fossils obtained at the Military Crossing of the Big Wichita, which are referred to the *N. winslowi* of Meek & Worthen. Although these specimens vary in certain respects from the type specimens as figured and described by the authors, they vary quite as greatly among themselves. These as well as other specimens indicate that the species is a very variable one, and its variability is believed to be so great as to include the *N. latus* of the same authors. The variability is observable in the different degree of acuteness of the lateral revolving angles, the prominence and shape of the nodes upon them, the difference of the convexity of the peripheral side, etc. The Texan specimens are also all smaller than the type specimens of *N. latus* and of *N. winslowi* respectively. Both the latter are from the Coal Measures of Illinois.

NAUTILUS OCCIDENTALIS Swallow.

Pl. II, Figs. 11, 12.

Nautilus occidentalis Swallow, Trans. St. Louis Acad. Sci., 1860, vol. 1, p. 196.
Nautilus biserialis Hall, Geology of Iowa, Supp., p. 92.

Some fragments, evidently belonging to this species, occur among the collections made at the Military Crossing of the Big Wichita. This species was originally described as coming from Permian rocks in Kansas, but it was afterward recognized as a common fossil in the Coal Measures of Illinois and Iowa.

NAUTILUS ——?

Pl. III, Figs. 6–8.

Compare with *N. eccentricus* Meek & Hayden, Palaeont. Upper Missouri, Smithson. Cont., 172 (1865), p. 65, Pl. II, Figs. 14*a*, 14*b*.
Also with *N. chesterensis* Meek & Worthen, Geol. Survey Illinois, 1866, vol. 2, p. 306, Pl. XXIV, Figs. 4*a*, 4*b*.

Associated with all the foregoing species are many examples of a small, plain *Nautilus*, which are too imperfect to be either satisfactorily described or identified with any published species. They may be compared with the two forms above cited, the first of which is from reputed Permian strata in Kansas, and the other from the Chester limestone, the uppermost member of the Lower Carboniferous group of Illinois.

NAUTILUS ——— ?

Pl. II, Figs. 7–10.

A couple of fragments of a plain subglobose *Nautilus* were found at the Godwin Creek locality, which are too imperfect for specific characterization, but they evidently belong to a different species from any of the foregoing, and it is also larger than the one last noticed.

NAUTILUS ——— ?

Pl. II, Figs. 4–6.

A few fragments of a discoid *Nautilus* were found at the Military Crossing locality which I am not able to refer to any published species, but which is similar in form and structure to *N. gravesianus* d'Orb., Pal. Française, Ter. Jur., 1850–'60, vol. 1, Atlas, Pl. XXXVIII.

NAUTILUS (ENDOLOBUS) ——— ?

Pl. II, Fig. 13.

The collections made at the Military Crossing locality contain a single fragment of a Nautiloid species, which is too imperfect for characterization further than to say that the septa show a small lobe, such as forms the leading feature of *Endolobus*, Meek & Worthen.

GASTEROPODA.

Genus NATICOPSIS McCoy.

NATICOPSIS REMEX White.

Pl. III, Fig. 10.

Naticopsis remex White 12th Ann. Rept. for 1878, U. S. Geol. Survey Terr., 1883, Part I, p. 139, Pl. XXXIV, Fig. 6.

Some internal casts of this species were found at both the Military Crossing and Godwin Creek localities. The type specimens of the species were obtained from the junction of the Grand and Green Rivers in Utah, from Carboniferous strata that are probably equivalent to the Coal Measures.

NATICOPSIS SHUMARDI McChesney.

Pl. III, Fig. 11.

Naticopsis shumardi McChesney, 1868, Trans. Chicago Acad. Sci., vol. 1, p. 49, Pl. II, Fig. 15.

Several specimens of *Naticopsis* were found at the Godwin Creek locality which seem to answer McChesney's description and figures of *N. shumardi* too nearly to warrant their reference to any other species. The type specimens of the species were obtained from Coal-Measure strata at La Salle, Illinois.

Genus EUOMPHALUS Sowerby.

EUOMPHALUS SUBQUADRATUS Meek & Worthen.

Pl. III, Fig. 9.

Euomphalus subquadratus M. & W., 1873, Geol. Surv. Illinois, vol. 5, p. 605, Pl. XXIX, Figs. 12, 13.

Several specimens of this species were found at the Military Crossing locality. The type specimens of the species were found in the Coal Measures of Illinois.

EUOMPHALUS ——— ?

Associated with the foregoing species some fragments of a shell were found which evidently belong to a species of *Euomphalus* different from the preceding; but they are too imperfect to admit of specific characterization.

Genus MURCHISONIA d'Archiac.

MURCHISONIA ——— ?

Pl. III, Figs. 12, 13.

Compare with *Murchisonia terebra* White, 12th Ann. Rept. for 1878 U. S. Geol. Surv. Terr., 1883, Part I, p. 139, Pl. XXXIV, Fig. 4.

The collection from the Military Crossing locality contains numerous examples of a *Murchisonia* all of which are in a bad state of preservation, and most of which are in the condition of casts of the interior of the shell. Enough of the shell substance, however, remains upon a part of them to show the form and ornamentation, the latter being quite variable. In the form of the shell and its volutions these specimens closely agree with *M. terebra* (loc. cit.), and some of the specimens vary but little from it in ornamentation. Others, however, show subordinate crenulated revolving ridges between the prominent peripheral ridge and the suture. The Texan shell is probably only a variety of *M. terebra*, the type specimens of which were obtained from Carboniferous strata in northern Arizona.

Genus PATELLA Linnæus.

PATELLA ? ——— ?

Pl. III, Fig. 14.

Compare with *Patella levettei* White, Geol. Indiana for 1881, p. 359, Pl. XXXIX, Figs. 4, 5.

Compare with *Leptopsis levettei* (White) Whitfield, Bull. Am. Mus. Nat. Hist., 1881–1886, vol. 1, p. 68, Pl. VIII, Figs. 8-12.

A single example of a Pattelloid shell was found at the Godwin Creek locality. In shape, size, and general character, it resembles the

shell from the Lower Carboniferous of Indiana which I described under the name of *Patella levettei;* but to which Prof. R. P. Whitfield afterward gave the generic name of *Leptopsis.* The Texan specimen, however, shows no indication of having had a coiled apex, and I therefore refer it provisionally to the genus *Patella.*

Genus BELLEROPHON Montfort.

BELLEROPHON CRASSUS, Meek & Worthen.

Bellerophon crassus, M. & W., Geol. Survey Illinois, 1866, vol. 2, p. 385, Pl. XXXI, Figs. 16*a*, 16*b*.

A couple of specimens of this species were found at the Military Crossing locality. They are too imperfect to be satisfactorily figured, but the specific characteristics are very well shown. The type specimens of the species are from the Coal Measures of Illinois.

BELLEROPHON MONTFORTIANUS, Norwood & Pratten.

Pl. III, Figs. 15, 16.

Bellerophon montfortianus, N. & P., Jour. Acad. Nat. Sci., Phila., 1855–1858, 2d ser., vol. 3, p. 74, Pl. IX, Fig. 5.

A single small example was found at the Godwin Creek locality, which is referred to the *Bellerophon montfortianus* of Norwood & Pratten with little or no hesitation. The type specimens were from the Coal Measures of Illinois, and it is not uncommon in strata of that age in adjacent States. It was also recognized by Prof. Geinitz among the Nebraska fossils, which he referred to the Dyas (Permian).

BELLEROPHON ———?

Many specimens of a moderately large *Bellerophon* were found among the fossils collected at the Military Crossing locality, all of which being in the condition of natural casts of the interior of the shell can not be satisfactorily figured and described. They seem to represent a different species from any of the others noticed in this bulletin.

CONCHIFERA.

Genus SEDGWICKIA McCoy.

SEDGWICKIA TOPEKAENSIS Shumard sp.

Pl. IV, Fig. 11.

Leptodomus topekaensis Shumard, Trans. St. Louis Acad. Sci., 1860, vol. 1, p. 208.

Sedgwickia topekaensis Meek & Hayden, Paleont. Upper Missouri (Smithsonian Cont., 172), 1865, p. 40.

At the Godwin Creek locality Mr. Cummins found a natural cast of the left valve of a shell which seems to be specifically identical with the form above indicated. The type specimens of the species which was used by both authors above cited were obtained from Coal-Measure strata in eastern Kansas.

Genus PLEUROPHORUS King.

PLEUROPHORUS ———?

Pl. IV, Figs. 5–10.

Natural casts of shells of *Pleurophorus* occur abundantly at the Godwin Creek locality. The extremes of difference in the form of these examples is so great that one can hardly forbear referring them at least to two species, but it is probable that the difference referred to is mainly that of sex, and in part that of age. Figures showing the principle varieties of form are given on Pl. IV. These specimens very likely represent one or more published species, but because of their imperfection no specific identification is attempted.

Genus CLIDOPHORUS McCoy.

CLIDOPHORUS OCCIDENTALIS Geinitz.

Pl. IV, Fig. 3.

Pleurophorus? occidentalis Meek & Hayden, Paleont. Upper Missouri (Smithsonian Cont., 172), 1865, p. 35, Pl. I, Fig. 2.

Clidophorus occidentalis Geinitz, Carbonformation u. Dyas in Nebraska, p. 23, Pl. II, Fig. 6.

Mr. Cummins obtained a single specimen at the Godwin Creek locality which seems to be identical with the form figured and described by Prof. Geinitz (loc. cit.).

Genus YOLDIA Möller.

YOLDIA? SUBSCITULA Meek & Hayden.

Pl. IV, Fig. 4.

Yoldia? subscitula Meek & Hayden, Paleont. Upper Missouri (Smithsonian Cont., 172), 1865, p. 60, Pl. II, Fig. 4.

Several specimens were obtained by Mr. Cummins at the Godwin Creek locality which closely answer the description and figure given by Meek & Hayden (loc. cit.). Their type specimen was obtained from reputed Permian strata in northeastern Kansas. There seems to be room for doubt whether this form ought not to be referred to the *Nucula* [*Nuculana*] *bellistriata* of Stevens, which is a common Coal-Measure species.

Genus MYALINA de Koninck.

MYALINA PERMIANA Swallow sp.

Pl. IV, Figs. 16–19.

Mytilus permianus Swallow, Trans. St. Louis Acad. Sci., 1860, vol. 1, p. 187.
Myalina permiana Meek & Hayden, Paleont. Upper Missouri (Smithsonian Cont., 172), 1865, p. 52, Pl. II, Fig. 7.

At the Camp Creek, Godwin Creek, and Military Crossing localities numerous specimens of *Myalina* were obtained which show a great variety of form, especially as regards marginal outline, but I think it not improbable that they nevertheless belong to one and the same species. Still the varieties that different authors have published under the respective names of *M. permiana*, *M. perattenuata*, and *M. aviculoides* are distinguishable among these Texan collections, and they will therefore be grouped under those three names respectively.

The form *M. permiana* was found at all three of the localities above named. The type specimens of both Swallow and Meek & Hayden were obtained from reputed Permian strata in Kansas.

MYALINA AVICULOIDES Meek & Hayden.

Pl. II, Fig. 12.

Myalina aviculoides M. & H., Paleont. Upper Missouri (Smithsonian Cont., 172), 1865, p. 51, Pl. II, Fig. 8.

A few specimens were found at the Godwin Creek locality, which have the outline and general features of the form to which Meek & Hayden gave the specific name of *aviculoides*. Their type specimens were obtained from the reputed Permian strata in Kansas.

MYALINA PERATTENUATA Meek & Hayden.

Pl. IV, Figs. 13–15.

Myalina perattenuata M. & H., Paleont. Upper Missouri (Smithsonian Cont., 172), 1865, p. 32, Pl. I, Fig. 12.

Specimens answering the original description of *M. perattenuata* were found associated with *M. permiana* at all three of the localities named in the foregoing notice of that form. Meek & Hayden's type specimens came from the Coal Measures of Missouri. It is not uncommon in the Coal Measures elsewhere.

Genus GERVILLIA Defrance.

GERVILLIA LONGA Geinitz.

Pl. IV, Fig. 2.

Gervillia longa Geinitz, Carbonformation u. Dyas in Nebraska, p. 32, Pl. II, Fig. 15. Compare with *Avicula shawneensis* Shumard, Trans. St. Louis Acad. Sci., 1860, vol. 1, p. 211.

Two specimens of an Aviculoid shell were obtained by Mr. Cummins at the Godwin Creek locality which are identified with the *Gervillia longa* of Geinitz, and they are perhaps identical with the *Avicula shawneensis* of Shumard. From an examination of the hinge of the Texan specimens the hinge area, although well developed and much like that of *Gervillia*, is found to bear no transverse cartilage pits, nor has the hinge proper any longitudinal teeth such as characterize *Gervillia*. The species is also known to occur in the Upper Coal Measures of different parts of the Mississippi Valley.

Genus AVICULOPECTEN McCoy.

AVICULOPECTEN OCCIDENTALIS Shumard sp.

Pl. IV, Fig. 1.

Pecten occidentalis, Shumard, First and Second Rept. Geol. Survey Missouri, 1865, part 2, p. 207, Pl. C, Fig. 18.

Pecton clearelandicus Swallow, Trans. St. Louis Acad. Sci., vol. 1, p. 184. Compare with *A. coreyanus* White, U. S. Geog. and Geol. Surveys West of 100th Merid., vol. 4, Part I, p. 147, Pl. II. Figs. 1*a*, 1*b*.

A single example of the left valve of this well known species was found at the Military Crossing locality. It is frequently found in characteristic Coal-Measure strata, and it has also been published as occurring in the reputed Permian strata of Kansas and Nebraska.

RADIATA.

POLYPI.

Genus SYRINGOPORA Goldfuss.

SYRINGOPORA ——— ?

A considerable number of specimens of a species of *Syringopora* were found at both the Camp Creek and Godwin Creek localities. They resemble the *S. multattenuatus* of McChesney, from the Coal Measures of Illinois, but the tubes are usually smaller.

ARTICULATA.

VERMES.

Genus SPIRORBIS Lamarck.

Pl. III, Fig. 17.

Numerous specimens of *Spirorbis* were found attached to the surface of the other fossils which were collected at the Military Crossing locality. It is not thought necessary to give a specific diagnosis of it, but it is figured for the purpose of presenting as complete an illustration of the fauna as is practicable.

CRUSTACEA.

Genus CYTHERE Müller.

CYTHERE NEBRASCENSIS Geinitz.

Pl. IV, Fig. 20.

Cythere nebrascensis Geinitz, Carbonformation u. Dyas in Nebraska, p. 2, Pl. I, Fig. 2.

The fossiliferous stratum at the Military Crossing locality contains multitudes of a small *Cythere* which I can not separate specifically from the *C. nebrascensis* of Geinitz.

GENERAL DISCUSSION.

It will be seen from the foregoing descriptions and notes that of the thirty-two species of invertebrates which are represented in the collections from the Texan Permian only four are recognized as new, all of these being cephalopods, and all belonging to the family *Ammonoidea*. The other species have been previously described and published, or their specific identity with published forms is in doubt because of the imperfection, either of the specimens in hand or of the manner of describing the species which they probably represent. Fifteen of the species are satisfactorily recognized as having been previously published. A part of them have been by some authors referred to the Permian, but the Coal-Measure age of the remainder has never been questioned. Some authors are of the opinion that not only all of the fifteen species just mentioned, but all North American invertebrates which have ever been referred to the Permian are really members of the fauna which characterizes the Coal-Measure period. Indeed, so generally has this view prevailed during the last twenty years that it is probable if the new cephalopods before mentioned were not present in the Texan collections no American paleontologist who is familiar with the Coal-Measure invertebrate fauna would hesitate to refer them all to that period.

So large a proportion of the invertebrate species which have been obtained from the reputed Permian strata in North America occur also in characteristic Coal-Measure strata that no satisfactory separation of them into two groups has hitherto been practicable upon the evidence of invertebrate fossils, and stratigraphical evidence also has hitherto been unsatisfactory. The collections, however, which are represented by the foregoing list and descriptions, although consisting mainly of Coal-Measure forms, contain at least two types which are so generally regarded as indicating the Mesozoic age of the strata containing them that if they alone and without any statement of correlated facts had been submitted to any paleontologist he would not have been warranted in referring them to an earlier period than the Trias if he had followed the usually accepted standard of reference. These two forms have been described on preceding pages under the names of *Waagenoceras cumminsi* and *Popanoceras walcotti* respectively. With the exception of *Ammonites parkeri* Heilprin,[1] also from Texas, similar types have not before been found associated with recognized Carboniferous species in North America.

This, however, is by no means the first nor the most important discovery of Mesozoic and Paleozoic types so commingled as to indicate that they all lived contemporaneously, and that they were all members of one and the same fauna. The remarkable discovery by Prof. Waagen in India (op. cit.) of many molluscan species belonging to Mesozoic types and associated with a characteristic Carboniferous fauna is well known. It is also known that Mesozoic characters are recognizable among some of the Carboniferous and Permian cephalopods of Armenia, as well as of Russia and certain other parts of Europe; and the later discovery in Sicily by Prof. Gemmellaro (op. cit.) is, next to that by Prof. Waagen in India, the most important of its kind.[2] These discoveries will be presently further referred to, but I wish first to consider briefly the bearing of the Texan discovery upon the question of the existence of the Permian in North America.

The special interest which these Texan collections possess lies, first, in the presence of the two cephalopods of Mesozoic types as members of an invertebrate fauna composed otherwise of Paleozoic types; second, in the association of these invertebrates with a vertebrate fauna composed mainly of Permian types, as determined by Prof. Cope; third, in the known superposition of the formation containing these faunas upon characteristic Coal-Measure strata; and fourth, in the probable absence of the Trias in the region where the Texan Permian occurs. The first point of interest relates to the paleontological interdelimitation of the Mesozoic and Paleozoic, and the second and third to the assumed Permian age of the Texan formation from which the collections discussed in this bulletin were made. The fourth point of interest relates to the upper delimitation of the Texan Permian.

[1] Proc. Acad. Nat. Sci., Philad., 1884, vol. 34, p. 53.

[2] See first foot-note on p. 10.

The paleontological interdelimitation of the Mesozoic and Paleozoic ages in geological history has long been regarded as clearly recognizable in all parts of the world. While it was well known that a considerable number of generic forms, especially of the invertebrates, occur in strata of both ages respectively, paleontologists have generally regarded it as a fundamental fact that certain orders, families, and even genera, which possess certain characteristics of structure and form, were rigidly confined to each age respectively. That is, they believed that the types which fall into the one category all ceased to exist at the close of the Paleozoic age, and that no member of the other category began its existence before the opening of the Mesozoic age. The presence of remains belonging to either the one or the other of these categories was therefore regarded as affording unquestionable proof of the geological age of the strata containing them. Attempts were made to explain the first discoveries of the commingling of earlier and later types in one and the same stratum, by assuming that the specimens showing earlier types of structure were derived in an already fossil condition from preexisting strata in the process of their destruction by which the materials for new strata were produced.

However unphilosophical those views concerning the chronological restriction of certain types may appear in the light of modern biology, it is not to be denied that until within comparatively few years paleontological observations in the field seemed, as a rule, to favor them, but such discoveries as those which have been made in India, Sicily, Russia and Texas show conclusively that animals belonging to both categories which have just been indicated lived contemporaneously. They show that some of those forms which have been regarded as exclusively Mesozoic in character began their existence while yet Paleozoic forms were far in the ascendant, and also that many Paleozoic forms survived their earlier associates, and lived in association with Mesozoic faunas. In the following general remarks upon the reputed North American Permian reference will be made to the bearing which the presence of Mesozoic types in the Texan Permian has upon the question of its true geological age.

From time to time during the last 30 years there have been discussions among geologists as to whether there is in North America any true equivalent of the Permian formation of Europe. Some writers have been uncompromising in their advocacy of the affirmative side of this question, and others have been equally positive in asserting the negative. Much of this difference of opinion has arisen from imperfect knowledge of essential facts, and much from want of a clear definition by the respective writers as to what they have regarded as constituting equivalency in this case. Within the last few years much addition has been made to our knowledge of facts bearing upon this question, and it is evident that clearer views upon it are now generally held than formerly prevailed, but it is too much to expect that the views of all

geologists should even now fully agree. The following statement presents the condition of this question, as the writer understands it. It is given to enable the reader to understand more clearly his views, and the reasons for the conclusions and opinions which are expressed in this bulletin.

In Europe the Carboniferous system is understood to be divided into three great groups, namely, the Lower Carboniferous, the Coal Measures, and the Permian, which are definable from one another, not only by paleontological, but by stratigraphical, characteristics. In North America the great Carboniferous system is quite as largely developed as in Europe. The Lower Carboniferous and Coal-Measure groups, upon both stratigraphical and paleontological grounds are as clearly recognizable and distinguishable from each other in some parts of this continent as they are in Europe, but the Permian has hitherto had no such undisputed recognition. Therefore, the question now to be considered is, whether the Permian of Europe has really an equivalent anywhere in North America, and if so, how that equivalency is recognizable.

In North America seven regions may be designated within which strata occur that have been, by different authors, referred to the Permian. These are: (1) southwestern Pennsylvania and northern West Virginia, (2) Prince Edward Island, (3) eastern Illinois, (4) northeastern Kansas and southeastern Nebraska, (5) South Park, Colorado, (6) isolated portions of New Mexico, Arizona, Utah, and western Colorado, and (7) northern Texas, together with the adjacent part of Indian Territory.

In all these cases there seems to be no room for doubt that the strata in question are not older than the Upper Coal Measures, as that formation is distinguishable in North America; but aside from their evidently high position in the Carboniferous system their recognition as Permian has been based upon different kinds of evidence, respectively. In the first and second mentioned cases it was based wholly upon plant remains; in the third upon vertebrate remains; in the fourth upon invertebrate remains; in the fifth upon plants and insects,[1] and in the sixth mainly upon stratigraphical position. The evidence in favor of the recognition of the strata as constituting a separate formation in the seventh case is presented in this article.

Two diverse ideas seem to have prevailed in the minds of those who have considered the question of the recognition of the Permian in North America. On the one hand the discovery on this continent of remains belonging to generic or other types of vertebrate, invertebrate, or plant life, which are respectively similar to forms found in the European Permian, has been regarded by some authors as surely indicating in each separate case the Permian age of the strata containing them, even if they were without any knowledge of correlated facts,

[1] These insects have, however, been referred to the Trias by S. H. Scudder, although they are associated with, perhaps, the most characteristic Permian flora that *has* been discovered on this continent.

whether paleontological or stratigraphical, or they formed that opinion without regard to them if known. On the other hand, it has been contended that no definite recognition of the Permian, even in the first-mentioned cases, ought to be made until after due consideration of all obtainable correlated paleontological and stratigraphical facts; and not then unless the preponderance of all that evidence should plainly favor such recognition.

The untenableness of the position indicated in the case first stated is shown by the facts mentioned in preceding paragraphs of the occurrence in one and the same stratum of forms which have been held to be characteristic of separate geological periods, and even of separate ages. It is conspicuously shown in the case of the Texan formation, which is specially discussed in this bulletin, because both its Coal-Measure age and its Triassic age can be even more readily proved, in an ex parte way, by special selections from its fossils, than its Permian age. And yet the sum of all the evidence is in favor of the latter.

The following paragraph from the work of Profs. William M. Fontaine and I. C. White[1] tersely states the principle which ought to govern the investigator in these cases, although it was written only with reference to the Permian age of the flora which they were then investigating:

> It is good evidence that we have to deal with a more recent formation when we find it to show a decadence of old forms and an introduction of new ones destined to reach their culmination at a later period. Thus if we find in a series of rocks plants characteristic of the Carboniferous formation, and perceive that these die out and disappear, we should not conclude from their mere presence that the age of the strata is Carboniferous, but rather that it is Permian. So also the finding of genera and species, even identical with those of the Trias or Jurassic would not necessarily imply a Triassic or Jurassic age. If we find them to be exceedingly rare, their presence is rather indicative of a formation older than the Trias or the Jurassic.
>
> It is only by taking into consideration all the above-named characters, and other points which may be presented by the entire body of specimens, that we can determine the nature of the evidence offered by the life of a formation. It will not suffice to say arbitrarily that this or that feature is without value as evidence. Circumstances might reverse the normal relative weight of evidence from the several sources and give preponderating weight to what would, if unaffected by them, have slight value.

Besides the observance of the principle enunciated by those authors, the investigator should remember the entire improbability that forms representing any distinguishing faunal or floral type have ever been simultaneously introduced in all parts of the world, and the now no less evident fact that forms representing certain types in some parts of the world long survived their extinction in other parts. He should also bear in mind the now evident fact that the rate of progressive development of vertebrate, invertebrate, and plant life respectively has not been uniform in all parts of the world. It therefore ought not to

[1] Permian or Upper Carb. Flora of West Virginia and S. W. Pennsylvania. Second Geol. Survey Pa., Rept. Prog. P.P. 1880, pp. 109, 110.

be expected that precisely the same association of types would be found on this continent that is found in Europe and elsewhere.

The difference of opinion which has prevailed concerning the existence of the Permian in North America has been shared even by those who recognize the importance of considering all the facts which bear upon each case of assumed equivalency of North American strata to the Permian of Europe. Some have believed that it should be strictly chronological as regards the whole of a given formation, while others claim that the most we can reasonably assume in any case is approximate contemporaneity, and all that we can ever certainly know in such cases is the homotaxial relation of formations with one another in different parts of the world, respectively. The scope of this bulletin, however, will admit of only a partial discussion of those views.

If all the time which is represented by the entire Carboniferous system in Europe is represented by the entire Carboniferous system of North America, the Permian of Europe must necessarily have a complete time equivalent somewhere on this continent. If that system is everywhere incomplete at the upper limit on this continent, and the same is complete in Europe, it necessarily follows that the stratigraphical time equivalent of the European Permian is either absent or incomplete in North America. But all the known facts which bear upon this case are of such doubtful value in their application to the question of strict chronological equivalency that it seems to be unprofitable to discuss it. Therefore the only question that remains to be considered in this connection is that of homotaxy.

The question, even after being reduced to these limits is a complex one, for it still involves the consideration of conflicting or disagreeing paleontological evidence, as well as a recognition of upper and lower delimiting boundaries of the formation. Besides this, formulary taxonomy has no real existence because geological systems are not subdivisible into the same, or even similar, units in widely separated parts of the world. Still there can be no good reason for doubting that there are in various parts of North America strata which are homotaxially equivalent, at least in part, to the Permian of Europe. But it is equally true that much of the reputed North American Permian can not be satisfactorily separated from the Coal Measures, and even those strata which have been separated more or less satisfactorily are found to be so intimately related to the Coal Measures as to make the lower limit indefinable.[2]

Heretofore also it has been impracticable to say whether the upper limit of the Carboniferous system in North America is complete or not. For example, none of the reputed Triassic strata, which occur in various

[2]In view of the last mentioned condition several American and European writers have applied the compromising term "Permo-carboniferous" to that undefinable upper portion of the Carboniferous system. Unfortunately, however, some American authors have of late applied that term to the whole Carboniferous series, seeming thereby to imply that the series includes an inseparable equivalent of the Permian, as well as of the remainder of the Carboniferous system.

parts of the continent, have been found in such relation to the reputed Permian as to indicate that there was continuous sedimentation from the one formation to the other; nor have those Triassic strata been found to contain any conclusive paleontological evidence of their immediate succession to the Permian. Indeed, as regards the remains of invertebrate life, the existence of any Triassic strata in North America rests upon comparatively slight evidence; slighter, indeed, than it might have seemed to be before the discovery of Triassic types associated with well known Carboniferous forms.[1]

The conflicting character of a part of the evidence afforded by the reputed North American Permian as to its age has already been shown, but there is an important case of want of harmony of different portions of certain accepted paleontological evidence that deserves mention. In Prof. Cope's Systematic Catalogue of the Permian vertebrate fauna of North America,[2] he shows that these remains have been discovered mainly in two limited districts, one in eastern Illinois and the other in Texas. His catalogue also shows that of the seventy-six species enumerated not one is, and of the thirty-two genera only five are, common to the two divisions. He also says that "the Permian vertebrate fauna of Illinois and Texas[3] exhibits close parallels, but not yet generic identity, on this continent."

On the contrary, the marine invertebrates which characterize the North American Coal Measures, a part of which usually range up into the reputed Permian, are widely distributed on this continent, and their geographical range includes both the Illinois and Texan vertebrate localities. That is, the invertebrate fauna referred to is uniform over a region in which the vertebrate fauna is diverse. In all the vertical and geographical range of these invertebrate fossils there has been observed no evidence of the decadence of old forms such as would be taken to indicate an approaching close to the geological period[4] which they have especially characterized; and it is only in the case of the Texan Permian that an introduction among them of new forms has yet been observed which might be regarded as forerunners of a new one.

Finally, while it is freely admitted that a considerable number of the

[1] The Triassic character of a part of the Permian fauna of Texas has been sufficiently stated, but it is also true that certain Carboniferous types occur in the Meekoceras beds of southeastern Idaho. Besides this those beds appear to have an intimate stratigraphical relation to the characteristic Carboniferous strata beneath them. Add to these facts the further one that types similar to those which have been relied upon in referring the Idaho beds to the Middle Trias also occur in undisputed Carboniferous strata, and it seems possible that those reputed Triassic beds ought to be referred to the Permian rather than to the Trias.

[2] Trans. Am. Philos. Soc., 1888, vol. 16, pp. 285–288.

[3] U. S. Geol. Survey Terr., 1884, vol. 3, p. 25.

[4] It has been pointed out by some authors that certain of the Brachiopods, and other species which characterize the Coal Measures, have never been found in any of the reputed Permian strata, and it seems to have been assumed that their absence was due to a final decadence of those forms before the Permian period was reached. It seems, however, not at all unreasonable to infer that intervening conditions differently affected certain of the classes of animals then living, in consequence of which they were differently dispersed.

invertebrate species which characterize the Permian of Europe have closely related representatives on this continent, it should not be forgotten that the latter are as characteristic of our undisputed Coal Measures as they are of the reputed Permian. Even if those forms are really specifically identical on the two continents it does not necessarily prove the contemporaneity of the respective formations containing them. In fact those formations must necessarily be of a difference in age equal to the time required by the geographical distribution of the species.

The recognition of the Permian in Texas as a separate upper group of strata belonging to the Carboniferous system is based upon both stratigraphical and paleontological evidence, and this evidence is fuller than that which has been adduced in favor of any other reputed Permian strata of North America. First, it contains invertebrate species which have been referred to the Permian in other districts northward from Texas, some of which are closely related to Permian species of Europe. Second, it contains the large vertebrate fauna published by Prof. Cope which he regards as characteristically Permian. Third, the Texan formation evidently constitutes an upper, apparently the uppermost, portion of the Carboniferous system. Fourth, the lithological difference between this formation as a whole and the Coal Measures beneath it, while not great, is sufficiently marked to make it conveniently distinguishable by the eye. Besides this the Mesozoic element which has been shown to exist among the invertebrates of the Texan Permian may properly be regarded as holding an opposite relation to the Paleozoic element, and thus to suggest a balance of paleontological evidence in favor of the Permian age of the formation.[1]

The present state of our knowledge, or of warranted opinion, as to the existence of the Permian formation in North America may be summed up briefly as follows:

Although in the region traversed by the Mississippi River the two earlier divisions of the Carboniferous system, namely, the Lower Carboniferous and the Coal Measures, are as clearly recognizable as they are in Europe, in many parts of this continent where Carboniferous strata are largely developed no separate recognition of either of those divisions, or of the Permian, is practicable.

In those regions where the Coal Measures or their equivalent are recognizable certain strata are sometimes found resting upon them which have been referred to the Permian, but those strata are, as a rule, not distinctly separable from the Coal Measures upon either stratigraphical or paleontological grounds. That is, no distinct stratigraphical plane of demarkation between the Coal Measures and the reputed Permian is observable. Besides this, many of the common Coal-Meas-

[1] It is admitted that the value of this suggestion is somewhat lessened by the known presence of the *Ammonites parkeri* of Hellprin in the underlying Texan Coal Measures, and by the presence of similar types beneath the Permian in certain parts of the Old World. Still, such forms as *Waagenoceras cummingsi* may properly be regarded as immediate harbingers of the Mesozoic age.

ure species range up into those Permian strata, and many acknowledged Permian types, according to the European standard, occur in the unquestioned Coal-Measure strata beneath them.

The upper limit of the Carboniferous system and the lower limit of the Trias have never been clearly recognized upon this continent, and it is therefore not now known that either of these systems are here at any point complete in that respect. But the upper limit of the Carboniferous system is known to be incomplete at most places where strata of that age occur.

A large part of the North American strata, which various authors have referred to the Permian, have no valid claim to be either so considered or to be considered as separate from the Upper Coal Measures. But a part of them may reasonably be assumed to be homotaxially equivalent with at least a part of the European Permian, although their delimitation from the Coal Measures may in most cases be difficult or impracticable.

The evidence upon which the Texan strata have been referred to the Permian is fuller than that which has been adduced with regard to any other North American strata that have been so referred. That is, the evidence both of the vertebrate and invertebrate fossils is in favor of such reference, and the difference in the character of the strata from those of the underlying Coal Measures, although not great, is conveniently distinguishable. Still, it is true that the Texan Permian strata bear many Coal-Measure invertebrate species, and that its flora at present is unknown.

In the foregoing discussions I have referred to the discovery of a molluscan fauna in Texan strata which contains both Mesozoic and Coal-Measure types as indicating that those strata are later in their origin than the Coal Measures; or, in other words, that they are of Permian age. While I think such a conclusion is correct in this case, especially when correlated facts are considered, it is by no means certain that Mesozoic forms similar to those found in the Texan strata were not introduced at a still earlier Carboniferous period than that which the Texan fauna is understood to represent.

That is, in view of our present knowledge of those Indian and Sicilian faunas that have been referred to on preceding pages, it seems probable that a considerable number of their Mesozoic molluscan types were really introduced in those parts of the world at an earlier epoch than the Permian. I am not now prepared to express a definite opinion upon this subject, but after examining the published works of Profs. Waagen and Gemmellaro, I am inclined to think that the strata from which they respectively obtained their commingled Mesozoic and Carboniferous forms are homotaxially equivalent to the Upper Coal Measures of North America, which strata belong beneath the Texan Permian.

In all the preceding discussions, as well as in the last paragraph, I have referred to certain of the mollusca of the Indian, Sicilian, and Texan faunas as being of Mesozoic types, and in accordance with the generally accepted views of paleontologists it is entirely proper to do so, but it is not to be denied that a part of the genera which have been recognized among those faunas have not yet been discovered in any other faunas, or in any other geological horizon than that of the upper portion of the Carboniferous system. In view of this fact the propriety of positively referring the types mentioned to the Mesozoic rather than to the upper portion of the Carboniferous may well be questioned. That is, it seems to be probable that while there is no error in referring a part of those commingled forms to the Paleozoic and a part to the Mesozoic, it is likely that certain members of those faunas which will be found to be characteristic of the upper portion of the Carboniferous system rather than of the earlier Mesozoic.

PLATES.

PLATE I.

MEDLICOTTIA COPEI (page 21).

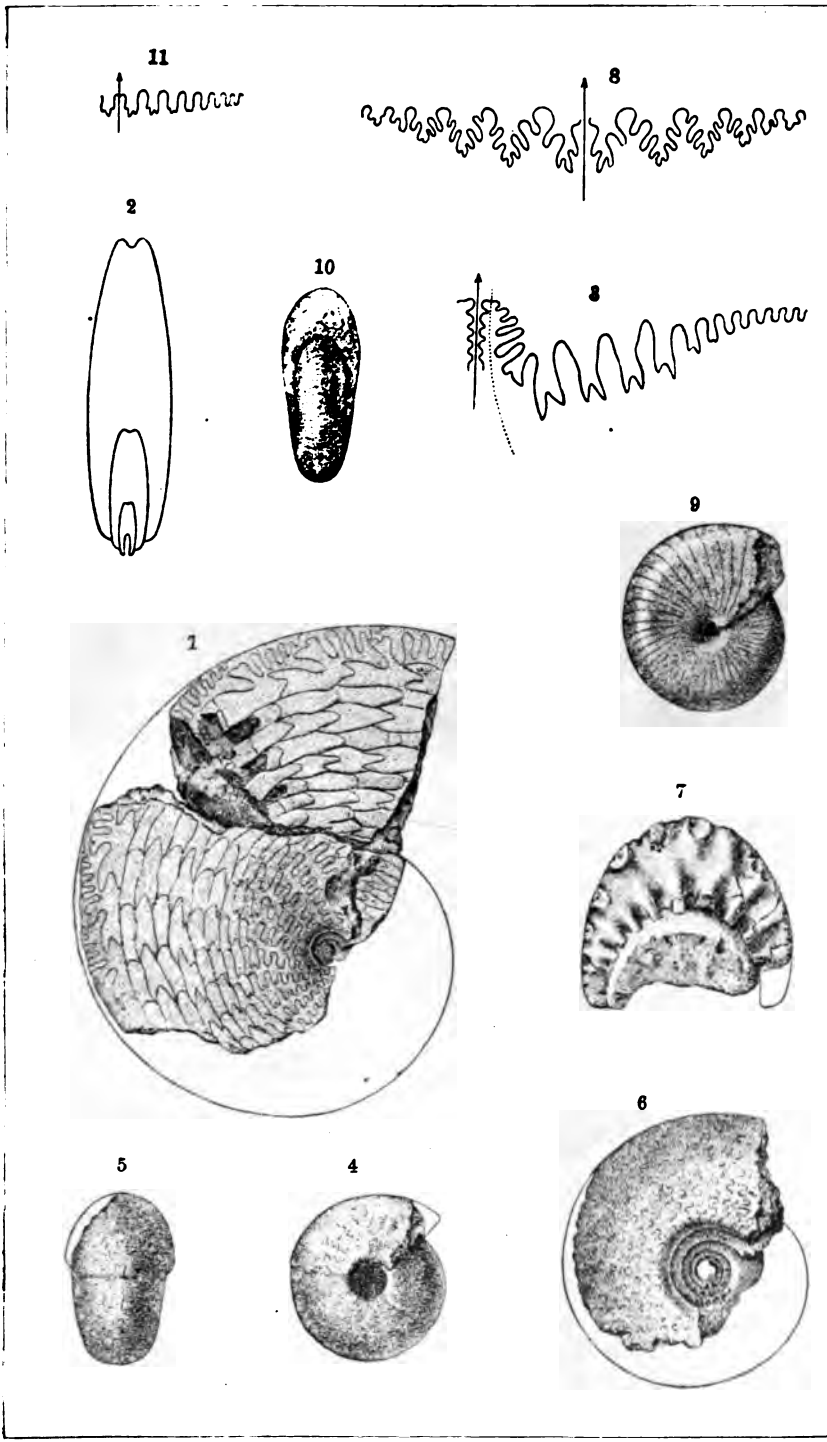
Fig. 1. Lateral view of an imperfect example.
Fig. 2. Diagrammatic section of the volutions.
Fig. 3. Septal suture.

WAAGENOCERAS CUMMINSI (page 20).

Fig. 4. Lateral view of a small example.
Fig. 5. Peripheral view of the same.
Fig. 6. Lateral view of a larger, imperfect example.
Fig. 7. View of septum of a still larger example.
Fig. 8. Septal suture of the same.

POPANOCERAS WALCOTTI (page 21).

Fig. 9. Lateral view of a small example.
Fig. 10. Peripheral view of the same.
Fig. 11 Septal view of the same.



INVERTEBRATE FOSSILS FROM THE TEXAN PERMIAN.

PLATE II.

PLATE II.

GONIATITES BAYLORENSIS (page 19.)

Fig. 1. Lateral view.
Fig. 2. Outline showing general form by peripheral view.
Fig. 3. Septal suture.

NAUTILUS ——? (page 24).

Fig. 4. Lateral view of an imperfect example.
Fig. 5. Outline of outer volution; restored from imperfect examples.
Fig. 6. Septal sutures from a broken example.

NAUTILUS ——? (page 24).

Figs. 7, 8, 9. Different views of a portion of a natural cast of interior of the shell.
Fig. 10. Outline of transverse section of a larger example, probably belonging to this species. Both examples are from Godwin Creek. Compare with Figs. 6, 7, 8. Pl. III.

NAUTILUS OCCIDENTALIS (page 23).

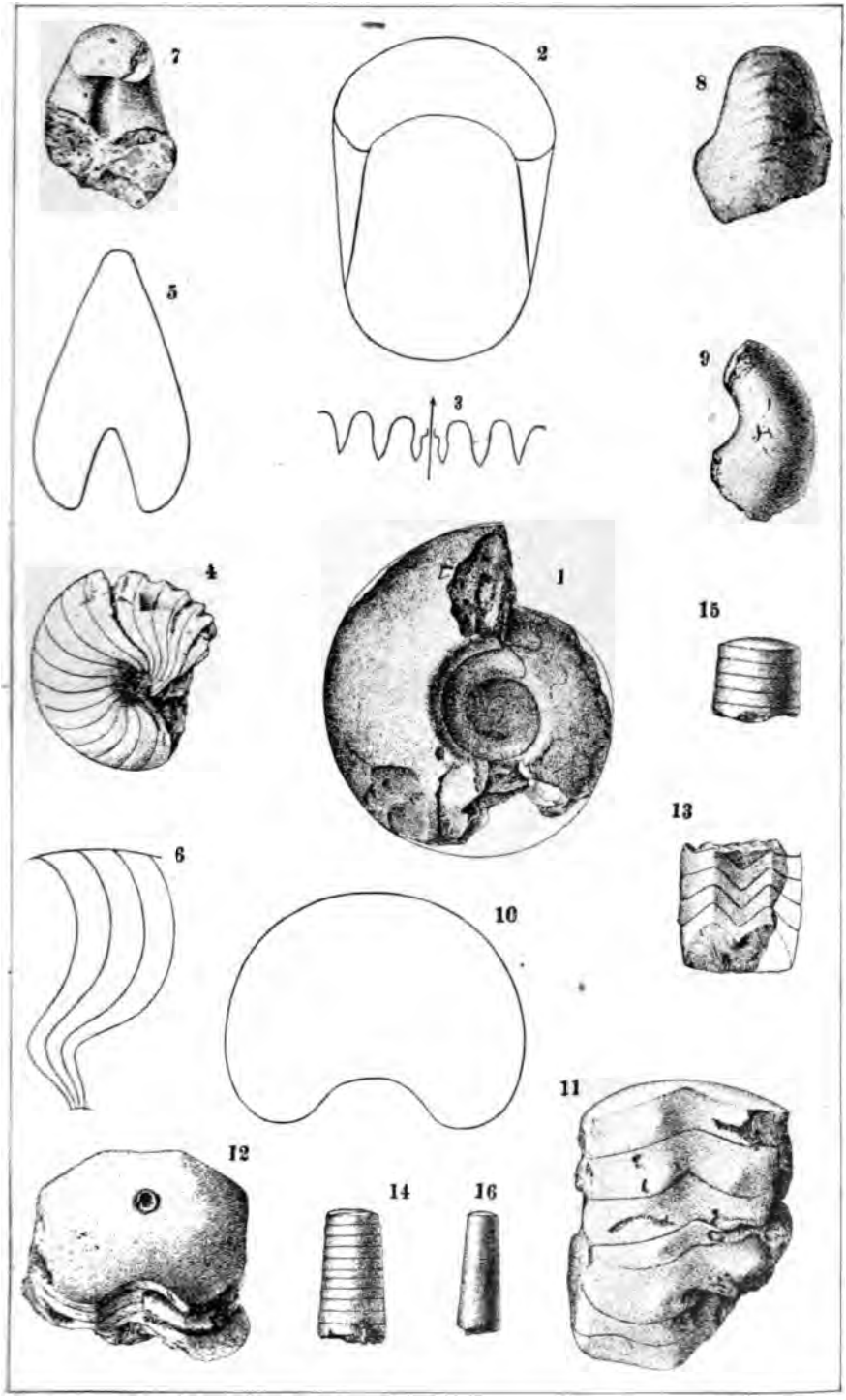
Fig. 11. Peripheral view of a fragment of a natural cast of the interior of the shell.
Fig. 12. End view of the same, showing septum and siphuncle.

NAUTILUS (ENDOLOBUS) ——? (page 24).

Fig. 13. View of a fragment showing the small median lobe at the inner border of the septum.

ORTHOCERAS RUSHENSIS (page 22).

Figs. 14, 15. Lateral view of two fragments showing septa.
Fig. 16. Similar view of a small example.



INVERTEBRATE FOSSILS FROM THE TEXAN PERMIAN.

PLATE III.

PLATE III.

NAUTILUS WINSLOWI (page 23).

Figs. 1, 2. Two views of a small example showing numerous small lateral lobes.
Figs. 3–5. Different views of three different examples showing varation as regards surface features.

NAUTILUS ——? (page 23).

Fig. 6. Lateral view of a very imperfect natural cast of the interior of the shell.
Figs. 7, 8. Two views of another example. Both examples are from Military Crossing. Compare with Figs. 7–10, Pl. II.

EUOMPHALUS SUBQUADRATUS (page 25).

Fig. 9. Apical view of a large example, somewhat distorted by pressure.

NATICOPSIS REMEX (page 24).

Fig. 10. Upper view of a natural cast of the interior of the shell.

NATICOPSIS SHUMARDI (page 24).

Fig. 11. Lateral view.

MURCHISONIA ——? (page 25).

Figs. 12, 13. Lateral view of two examples showing difference in surface ornamentation.

PATELLA ——? (page 25).

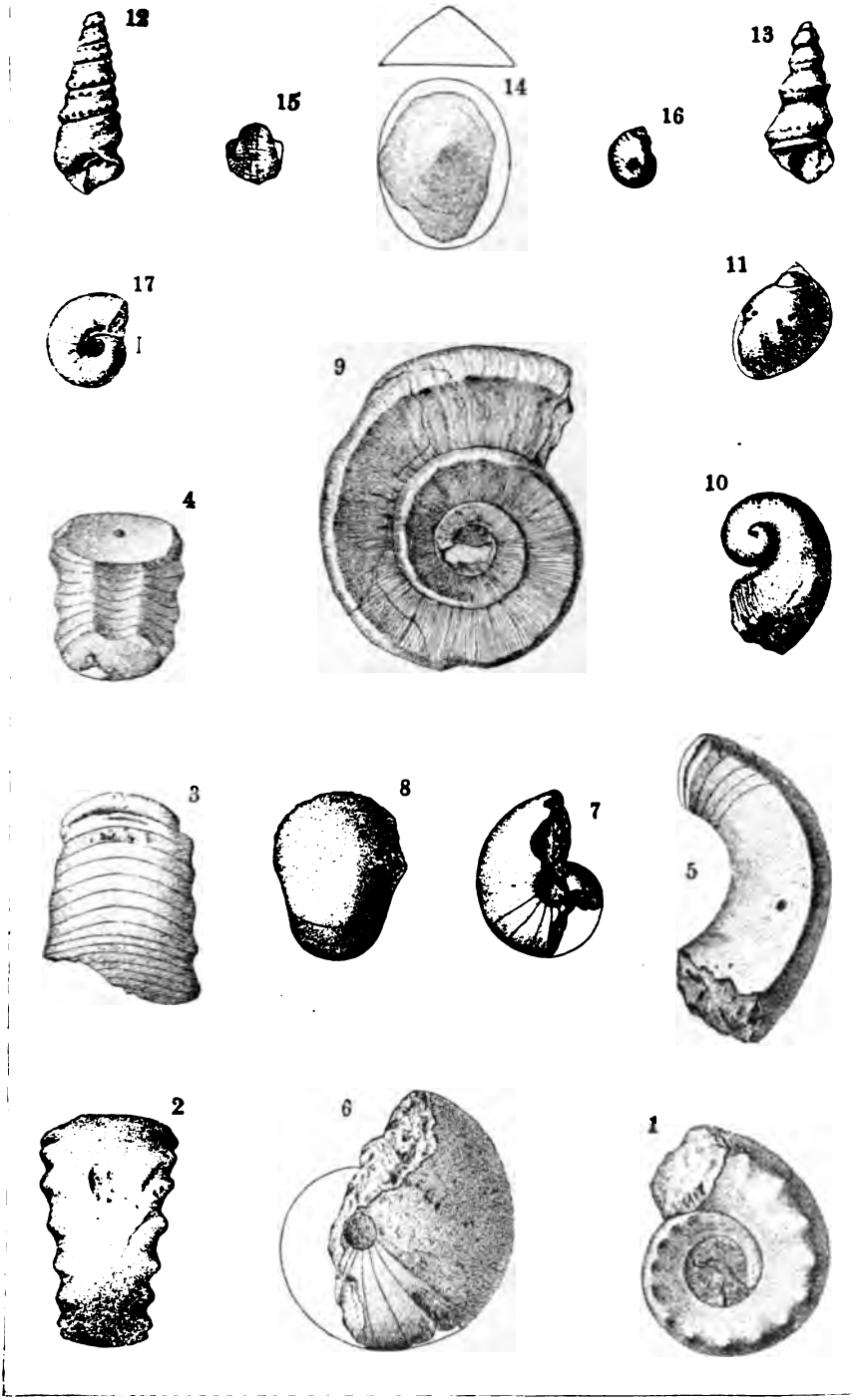
Fig. 14. Dorsal view and surface outline of transverse section.

BELLEROPHON MONTFORTIANUS (page 26).

Figs. 15, 16. Two views of a small example.

SPIRORBIS ——? (page 30).

Fig. 17. Upper view, much enlarged.
All figures of natural size except the last, which is much enlarged.



INVERTEBRATE FOSSILS FROM THE TEXAN PERMIAN.

PLATE IV.

PLATE IV.

AVICULOPECTEN OCCIDENTALIS (page 29).

Fig. 1. Left valve.

GERVILLIA LONGA (page 29).

Fig. 2. Left side view.

CLIDOPHORUS OCCIDENTALIS (page 27.)

Fig. 3. Right side view.

YOLDIA? SUBSCITULA (page 27.)

Fig. 4. Left side view.

PLEUROPHORUS——?

Fig. 5. Left side view of a natural cast of the interior of the shell.
Fig. 6. Dorsal view of the same.
Figs. 7, 8. Right side view of the two natural casts of the interior of the shell.
Fig. 9. Similar view of another broader example.
Fig. 10. Right side view of an artificial cast, showing surface markings.

SEDGWICKIA TOPEKAENSIS (page 26).

Fig. 11. Lateral view of a natural cast of the interior of a left valve.

MYALINA AVICULOIDES (page 28.)

Fig. 12. Right side view of a natural cast of the interior of the shell.

MYALINA PERATTENUATA (page 28.)

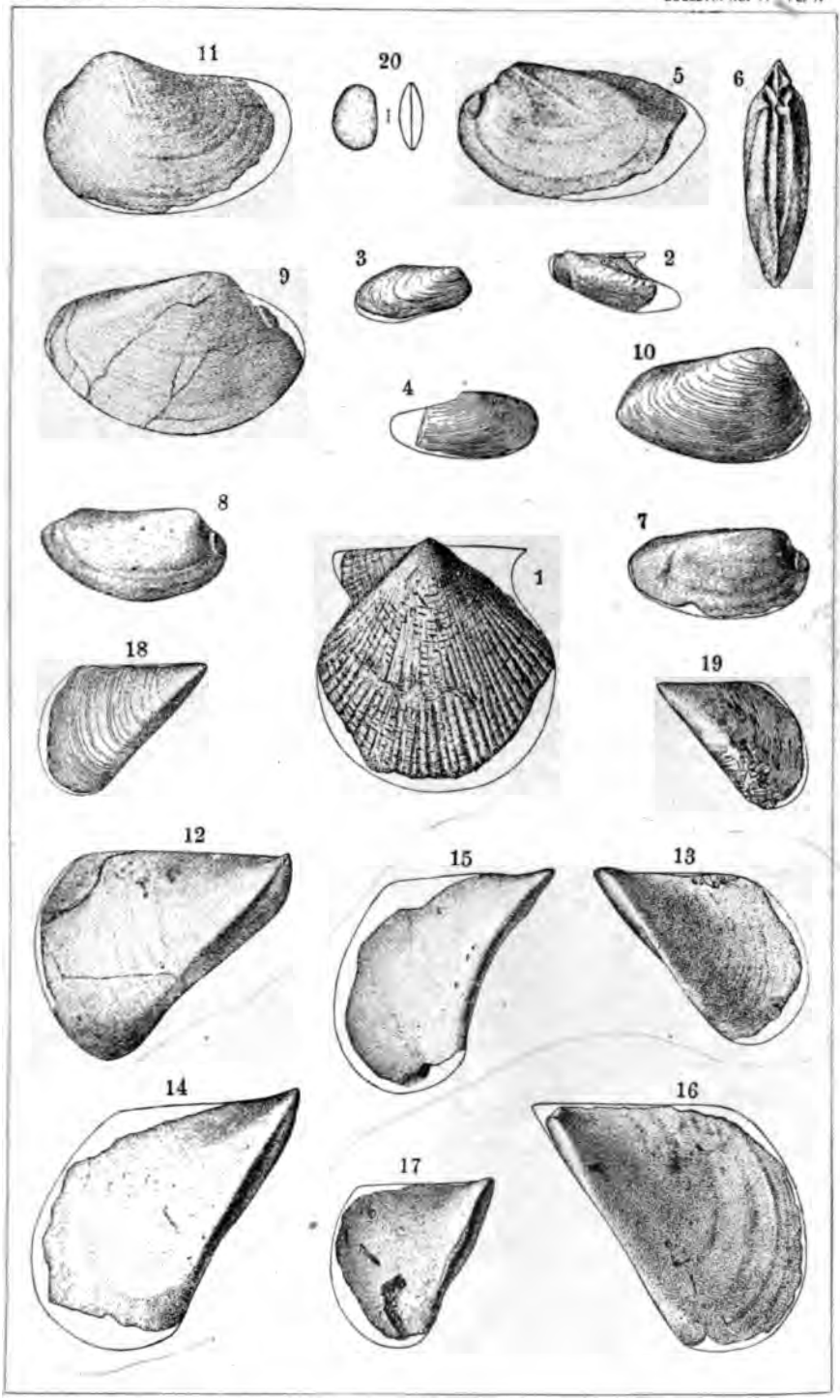
Fig. 13. Left side view of an example from Camp Creek.
Fig. 14. Right side view of an example from Godwin Creek.
Fig. 15. Similar view of an example from Military Crossing.

MYALINA PERMIANA (page 28.)

Fig. 16. Left side view of an example from Godwin Creek.
Fig. 17. Right side view of an example from Camp Creek.
Figs. 18, 19. Right and left side views of two examples from the Military Crossing.

CYTHERE NEBRASCENSIS (page 30.)

Fig. 20. Lateral view and vertical outline, much enlarged. All except Fig. 20 are of natural size.



INVERTEBRATE FOSSILS FROM THE TEXAN PERMIAN.

INDEX.

	Page.
Ammonites parkeri Heilprin, in Carboniferous of Wise County, Texas	31
Archer County, fossils found in	9, 15
copper ores in	10
Aviculopecten occidentalis	29
Baylor County, fossils found in	15
Bellerophon crassus	26
montfortianus	26
——?	26
Big Wichita, Military Crossing of	15
Camp Creek, fossils found at	15
Clidophorus occidentalis	27
Coal Measures, a division of the Carboniferous system	9
Mesozoic coal-bearing strata, often so called	9
of Texas	13
Cope, E. D., cited on Permian fossils	12
Copper ores in Texan Permian	10
Cummins, W. F., discovery of Permian fossils by	9
Information received from	9
Cythere nebrascensis	30
Enomphalus ——?	25
subquadratus	25
Fontaine, W. M., and I. C. White, remarks on the Permian quoted	34
Fossils (invertebrate), list of, in Texan Permian	16
Localities of, in Texan Permian	15
Gemmellaro, G. G., cited on Sicilian fossils	9, 10
Geological maps of McGee and Hitchcock cited	10
Gervillia longa	29
Godwin Creek, fossils found at	15
Goniatites baylorensis	19
Gypsum-bearing beds	13
fossils found in	13
Heilprin, Angelo, cited with reference to Ammonites parkeri	31
Hitchcock, C. H., geological map cited	10
India, Mesozoic forms in the Carboniferous strata of	9
Indian Territory, Permian of	11
McGee, W. J., geological map cited	10
Meekoceras beds of Idaho, possibly Permian	36
Medlicottia copei	21
Mesozoic types of fossils in Texan Permian	9, 31
Military Crossing of the Big Wichita, fossils found at	15
Murchisonia ——?	25
Myalina aviculoides	28
perattenuata	28
permiana	28
Naticopsis remex	24
shumardi	24
Nautilus occidentalis	23
winslowi	23
——?	23
——?	24
——?	24
North American Permian, regions of	33
Old Military Crossing, a settler's term	15
Orthoceras rushensis	22
Patella? ——?	25
Permian in North America discussed	32
Permian of Texas, copper ores in	10
descriptive section of	15
invertebrate fossils of	16, 30
Permian regions of North America	33
Permo-Carboniferous, a compromising and objectionable term	35
Pleurophorus ——?	27
casts of, found in gypsum-bearing beds	13
Popanoceras walcotti	21
Ptychites cumminsi	20
Scudder, S. H., on fossil insects of South Park, Colorado	33
Section, descriptive, of Texan Permian	15
Section, general, of Texan formations, illustrated	14
Sedgwickia topekaensis	26
Sicily, Mesozoic forms in carboniferous strata of	9, 10
Spirorbis ——?	30
Syringopora ——?	29
Systematic catalogue of Permian vertebrates by E. D. Cope, cited	9
Triassic, probable absence of, in Texas	13
Waagen, W., cited on fossils of the Salt Range, in India	9
Waagenoceras cumminsi	20
White, I. C., and W. M. Fontaine, remarks on the Permian quoted	34
Yeates, W. S., qualitative analysis of copper ores by	10
Yoldia? subscitula	27

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 78

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

REPORT OF WORK DONE

IN THE

DIVISION OF CHEMISTRY AND PHYSICS

MAINLY DURING THE

FISCAL YEAR 1889-'90

FRANK WIGGLESWORTH CLARKE, CHIEF CHEMIST

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

CONTENTS.

	Page.
Preface	9
Experiments upon the constitution of the natural silicates; by F. W. Clarke and E. A. Schneider	11
Olivine	13
Talc	13
Serpentine	15
The chlorite group	19
The micas	24
The vermiculites	28
Final considerations	31
The relative abundance of the chemical elements; by F. W. Clarke	35
On the occurrence of nitrogen in uraninite, and on the composition of uraninite in general; by W. F. Hillebrand	43
General introductory remarks	43
Preparation of samples for analysis	45
Methods of analysis	46
Detection and examination of nitrogen	53
Estimation of nitrogen	56
Analysis of uraninite	60
Bohemian and Saxon uraninite	72
Discussion of analyses	73
Special experiments relating to the nitrogen in uraninite	76
Effect of heating in air	76
Effect of heating in carbonic acid gas	77
Effect of heating in hydrogen	77
Conclusions	78
Metacinnabarite from New Almaden, California; by W. H. Melville	80
An apparatus for the determination of water in mineral analysis, by Thomas M. Chatard	84
The separation of titanium, chromium, aluminum, iron, barium and phosphoric acid in rock analysis, by Thomas M. Chatard	87
Seven New Meteorites, by L. G. Eakins	91
Stony meteorite from Texas	91
Meteoric iron from North Carolina	93
Pallasite from Kansas	94
Meteoric iron from Texas	95
Meteoric iron from Chili	95
Chondrite from Iowa	95
Llano del Inca meteorite	97
On a petroleum from Cuba; by H. N. Stokes	98
Paraffins	100
Unsaturated fatty hydrocarbons	100
Aromatic hydrocarbons	100
Naphthenes	101

Page.
On a supposed mineral resin from Livingston, Montana; by H. N. Stokes..... 105
Preliminary notes on the coefficients of thermal expansion of certain rocks; by William Hallock..... 109
Methods..... 109
Materials..... 115
Miscellaneous analyses..... 119
Astrophyllite..... 119
Brown hornblende..... 119
Kyanite..... 120
Liebenerite?..... 120
Kaolin..... 120
Picrallumogene..... 121
Brochantite..... 121
Keratophyr from Marblehead Neck, Massachusetts..... 121
Websterite from North Carolina and Maryland..... 122
Feldspars from Minnesota gabbros..... 122
Eruptive rock from Montana..... 123
Rocks from California..... 123
Sandstone from Arizona..... 124
Limestone from Kansas..... 124
Five Cherokee limestones..... 125
Ores of iron..... 125
Ores of manganese..... 127
Two coals from West Virginia..... 128
Water from Webster Grove, Missouri..... 129
Brass..... 129

ILLUSTRATIONS.

		Page.
FIG. 1.	Apparatus for collecting nitrogen	56
2.	Metacinnabarite crystals	82
3.	Apparatus for determination of water	84
4.	Pycnometer	110
5.	Apparatus for measuring penetration of temperature	112
6.	Comparator used in determining rock expansions	113
7.	Apparatus for comparison of expansions	114
8.	Portion of preceding apparatus	115
9.	Diagram showing expansion of a bar of marble on wetting	118

PREFACE.

This bulletin, like the bulletins issued in previous years and numbered 9, 27, 42, 55, 60, and 64, contains a partial record of work completed in the chemical and physical laboratories of the Survey during one fiscal year. It represents, however, only a portion of the whole work done, for various investigations, begun during the year 1889–'90, are still unfinished; many analyses are reserved for publication in other reports; and certain of the larger researches, notably the physical studies of Dr. Barus, will appear in independent form as separate bulletins. In the annual reports of the Director of the Survey a tolerably complete summary of the work done in the Division of Chemistry and Physics is always given, and such summaries, taken in connection with these bulletins, convey a fair idea of the amount of ground actually covered.

WORK DONE IN THE DIVISION OF CHEMISTRY AND PHYSICS IN 1889–'90.

EXPERIMENTS UPON THE CONSTITUTION OF THE NATURAL SILICATES.

BY F. W. CLARKE AND E. A. SCHNEIDER.

During the last six years the constitution of the natural silicates has received a good deal of attention in the laboratory of the U. S. Geological Survey. A number of papers have been published by one of us, partly theoretical and partly analytical, but the evidence so far considered has been drawn only from careful analyses of various minerals, and a study of their obvious relations, their associations, and their alteration products. Within certain limits the results obtained have been satisfactory and suggestive, but in several cases it was found that ordinary analysis failed to discriminate between possible alternative formulæ, and it was plain that the uncertainties could be cleared up only by new lines of experimental investigation. With such investigations the present paper has to do. Sixteen minerals, including varieties, all of the magnesian class, have been examined, and it has been found quite possible to separate some of them into distinct fractions of definite character in such a way as to shed much light upon their inner chemical structure. In general the methods which have been employed by us are not new, except in their application to the silicate problem, but in their analogies to the processes used for the elucidation of organic compounds we believe that they will be found interesting.

In brief our mode of procedure has been as follows: First, each mineral, selected and purified with great care, has been completely analyzed, and in each case enough material was ground to a uniform sample to suffice for all subsequent experiments. Secondly, each mineral has been subjected to the action of *dry* hydrochloric acid gas under quantitative conditions. For this purpose a quantity of material was weighed out in a platinum boat, which was then placed in a glass tube and heated in a stream of the dry gas until, after repeated weighings,

constant weight was attained. The sample was then treated with water and a drop or two of nitric acid, and the soluble constituents of the mass were determined by the usual methods of analysis. In every instance a sample was thus treated at a temperature between 383° and 412° C., but in some cases other temperatures were studied also. For heating the tubes an ordinary combustion furnace was used, and the temperature was kept within the indicated range by placing on one side of the platinum boat a sealed capillary tube containing lead iodide, melting point 383°, and on the other side a tube containing zinc, which fuses at 412°. The flames of the furnace were then so adjusted that the iodide fused, while the zinc did not. For a higher range of temperatures, which was employed in some cases, the indicators similarly used were lead chloride, m. p. 498°, and silver iodide, m. p. 527°. These melting points are given according to Carnelley. As a rule, in each series of experiments the sample under treatment was weighed every two hours, and before reheating was stirred with a fine platinum wire in order to expose a fresh surface to the action of the acid. By this mode of treatment different minerals are very differently affected, there being almost no action in some cases, and very notable action in others. With this action of gaseous acid, the action of aqueous hydrochloric acid upon each mineral was carefully compared, and some points of great importance were thus brought out. As a rule one gramme of mineral was treated with 75cm³ of fuming hydrochloric acid on the water bath, and the mixture was evaporated to dryness. When decomposition was not complete, the mineral was further treated with hydrochloric acid of sp. gr. 1·12 for three days or even longer, and the amount of action was ascertained and recorded. In several instances this treatment with aqueous acid was repeated after strong ignition of a mineral, and it was sometimes found that a species previously soluble could be thus split up into a soluble and an insoluble part. In a number of cases ignition of a mineral caused the liberation of silica, which could afterward be dissolved out with soda solution and quantitatively determined. For this purpose a solution of sodium carbonate, 250 grammes to the litre, was employed. Finally, in almost every case the nature of the water in a mineral was investigated, by a study of the temperatures at which its several fractions were expelled. For low temperatures, an ordinary air bath was used; for higher temperatures the minerals were heated in a stream of dry air, between indicators of known melting points, just as in the treatment with gaseous hydrochloric acid.

So much for the methods of research, which will be more clearly understood from a study of the details to be given presently. On the theoretical side we have adhered to the working hypothesis that the more complex silicates are substitution derivatives of normal salts, as has been suggested by one of us in several earlier publications. From this point of view the normal orthosilicate of magnesium is the fittest *starting* point for discussion, and this salt is approximately represented *by olivine. The purer forsterite* was not available.

OLIVINE.

For this species the only material at hand was a supply of the chrysolite pebbles from near Fort Wingate, New Mexico. The mineral from this locality, we believe, has not been previously analyzed; and as it is rich enough in color and is sufficiently clear it is often cut as a gem. It has the characteristic color of the peridot, and is apparently quite free from inclusions. The analysis gave the following results:

SiO_2	41·98
Fe_2O_3	·51
FeO	5·71
NiO	·42
MnO	·10
MgO	51·11
H_2O	·28
	100·11

Only 0·05 per cent. of the water was lost at 105°.

1·1027 grammes of the mineral were heated in gaseous hydrochloric acid for twenty-two hours, and gained in weight 0·0157 grm. On leaching with water and a drop of nitric acid the following percentages of material went into solution:

MgO	1·47
Fe_2O_3	·43

Hence olivine, at the temperature of 383°–412°, is hardly attacked by dry hydrochloric acid; and the slight action here recorded may possibly be due to incomplete drying of the gas. The aqueous acid, on the other hand, decomposes olivine with great ease. On this mineral no other experiments were necessary for our purposes.

TALC.

The mineral studied was a typical, apple-green, foliated talc from Hunter's Mill, Fairfax County, Virginia. Analysis as follows:

SiO_2	62·27
Al_2O_3	·15
Fe_2O_3	·95
MgO	30·95
FeO	·85
MnO	trace
H_2O	4·91
	100·08

In detail, the water determination was as follows:

Loss at 105°	·07
Loss at 250°–300°	·06
Loss at red heat	4·43
Loss at white heat	·35

Hence the water is practically all constitutional.

Heated in dry HCl gas to 383°–412° for fifteen hours, the talc underwent inappreciable change of weight. Upon leaching, only 0·23 per

cent of magnesia went into solution. By rapid evaporation with 75 cc. of fuming aqueous HCl, 1·05 per cent of MgO and 0·16 of $(FeAl)_2O_3$ were dissolved. Upon eight days' digestion on the water bath with acid of 1·12 sp. gr., 1·94 MgO and 0·23 of sesquioxides were removed. By digesting in like manner for thirty-two days, 3·94 MgO and 0·41 of sesquioxides were taken out. Talc, therefore, is, as should have been expected, remarkably stable in presence of hydrochloric acid, both aqueous and dry. This fact has a very important bearing upon the constitutional formula of the mineral.

In empirical composition the talc analyzed agrees quite sharply with the accepted formula $Mg_3H_2Si_4O_{12}$. This is commonly interpreted as an acid metasilicate, $Mg_3H_2(SiO_3)_4$; but Groth has lately proposed to consider talc as a basic salt of pyrosilicic acid, $H_2Si_2O_5$. On this supposition its rational formula becomes $Mg(Si_2O_5)_2(MgOH)_2$. Between these two formulæ, experiment is able to decide.

Against Groth's formula the stability of talc towards acids tells very strongly. The univalent group —Mg—OH ought to be soluble in hydrochloric acid; and evidence, to be presented later, goes to show that that particular group is easily removable by the dry, gaseous HCl. In fact, our experiments make it highly probable that all the magnesia taken from a silicate by perfectly dry HCl was originally present in the hydroxylated form. As regards the constitution of talc, however, other evidence is even stronger.

If Groth's formula is correct, then, upon ignition, talc should behave according to the equation

$$Mg<\begin{matrix}Si_2O_5—Mg—OH\\Si_2O_5—Mg—OH\end{matrix}—H_2O=Mg<\begin{matrix}Si_2O_5—Mg\\Si_2O_5—Mg\end{matrix}>O.$$

In other words the loss of water should produce but little change, and no silica should be liberated. If, on the other hand, the acid metasilicate formula is true, talc should split up into $3MgSiO_3+SiO_2+H_2O$; that is, one-fourth of the silica should be set free; which, in the present instance, would amount to 15·57 per cent. This actually happens; and a weighed quantity of talc, ignited very intensely for half an hour over a blast-lamp, gave up 15·36 per cent of SiO_2 upon subsequent boiling with a solution of sodium carbonate. Upon longer ignition, as might be expected, a part of this silica reverts to the insoluble form, and somewhat lower results are obtained. Upon the unignited talc, boiling with soda solution for 24 hours produced little or no effect; soda was not taken up, nor was silica removed.

In brief, both lines of evidence, the liberation of silica and the stability toward acids, confirm the ordinary formula for talc and controvert the views of Groth; and no other formula, out of several which are possible, satisfies both of the experimentally established conditions. The mineral, therefore, must be regarded as an acid metasilicate; although its ultimate structural formula can be written only when we

have a better knowledge of metasilicic acid. It is a noteworthy fact, that no normal metasilicic ether is yet certainly known; for Ebelmen's results have not been confirmed by later observers. Troost and Hautefeuille, however, prepared an ether having the composition $(C_2H_5)_8Si_4O_{12}$. Possibly enstatite may be the normal magnesium salt corresponding to this ether; in which case talc would be a substitution derivative having H_2 in place of one atom of Mg.

SERPENTINE.

On account of the importance of this species, its variability in external characteristics, and its manifold relations to other minerals, several distinct samples were investigated.

A. Dull green serpentine from Montville, New Jersey, derived from pyroxene by alteration.

B. Dark green serpentine from the well known locality at Newburyport, Massachusetts.

C. Silky, fibrous chrysotile from Montville.

D. Grayish green picrolite from Buck Creek, North Carolina.

E. A grayish green mineral from Corundum Hill, North Carolina, which was supposed at first to be deweylite. It is an ordinary, massive serpentine.

Analyses as follows, with the itemized water determinations subjoined:

	A	B	C	D	E
SiO_2	42·05	41·47	42·42	42·94	41·90
H_2O	14·66	15·06	15·64	13·21	16·16
MgO	42·57	41·70	41·01	36·53	40·16
FeO	·10	·09	undet.	1·88	undet.
CaO	·05	none.	trace.	.....	.....
NiO	.....	.....	·23	·61	·10
Fe_2O_3	·30	1·73	·62	3·33	·91
Al_2O_3	.....		·63	1·72	·71
	99·73	100·05	100·55	100·22	99·94
H_2O at 105°	·96	1·20	2·04	1·53	2.26
H_2O at 250°	·55	·55	·71	.44	1·01
H_2O at 383°–412°	·27	.....	·27	·62	·98
H_2O at 498°–527°	·23	.....	·56	.....	·42
H_2O at red heat	12·37	13·01	11·81	10·58	11.32
H_2O at white heat	·28	·30	·25	·04	.17

From these data it is clear that practically all the water in serpentine is constitutional, and that none of it can be fairly regarded as crystalline. The small, variable amount lost below 250° is mainly hygroscopic and inclosed water, since the analyses refer to air-dried material. It is hardly necessary to state that in each fractional determination the material was heated to constant weight.

Upon heating in dry, gaseous hydrochloric acid all of these serpentines were stongly attacked; differing essentially in this particular from olivine and talc. The bases thus taken out as chlorides at 383°–412° were as follows:

	A	B	C	D	E
No. hours heated	54	68	54	78	41
MgO extracted	10·14	16·73	9·98	11·38	15·25
R_2O_3 extracted	.....	·43	.....	·66	·51

In the last determination the soluble magnesia was accidentally lost; and the value given was estimated by difference. A duplicate determination on the Newburyport mineral, at the same temperature, with 39 hours' heating gave only 14·43 per cent of magnesia removed as chloride. The different times required for obtaining constant weight and so fixing the limit of the reaction vary considerably.

Similar experiments upon serpentines A and B at the temperature 498°–527° gave similar results.

	A	B
Hours heated	18	18
MgO removed	10·83	14·28
R_2O_3 removed	·10	·16

In duplicate determinations at the same temperature, A yielded 14·17 and B gave 17·36 per cent of magnesia converted into chloride.

Now these data, although not satisfactorily concordant, have nevertheless some significance. They show first that the action of the gas is much the same at both of the temperature intervals, except that the limit of change is reached more quickly in the hotter series. They show, also, that the magnesia of serpentine is probably combined in two ways; one part being affected, the other unattacked by the acid. That part which is converted into chloride, and so rendered soluble, we may regard provisionally as represented by the group —Mg—OH; even though our estimate of its amount may not be so sharply accurate as might be desirable. No other hypothesis as to the nature of the dissolved magnesia seems to be practicable, or to account in any way for the results of the experiments. Roughly speaking, a maximum amount of *about* one-third of the magnesia in serpentine is extracted by dry HCl under the conditions of our experiments, the other two-thirds being more stable.

By aqueous hydrochloric acid all of the five serpentines were easily and completely decomposed. In three instances this fact was determined quantitatively; by evaporating the acid to dryness with the mineral, extracting with weak acid, and weighing the residue. In each

case this residue agreed in percentage with the silica found by actual analysis. The data are as follows:

	A	C	D
Insoluble in HCl	42·32	42·21	42·55
Silica found	42.05	42·42	42·94

By very weak hydrochloric acid, however, these three serpentines are but partially decomposed; the picrolite being the most stable of the series. A microscopic examination of the picrolite by Mr. Waldemar Lindgren showed no inclusions which could account for this difference in behavior, and it is probably due to merely mechanical conditions.

Upon boiling directly with sodium carbonate solution, none of the serpentines were attacked. By sharp ignition, however, a little silica was sometimes liberated; which, as in the case of the talc, could be dissolved out and estimated. The quantities of silica thus set free were as follows:

	A	B	C	D	E
Per cent	6·23 6·34	2·00 2·63	2.98	none	6·05 4·93

These results can not easily be interpreted. At most, only about one-seventh of the total silica is thus taken out; and this may represent either impurities in the minerals or secondary reactions of an undetermined kind.

When serpentine is heated to the point of fusion it is split up, as Daubrée has shown[1], into a mixture of olivine and enstatite.

$$H_4Mg_3Si_2O_9 = 2H_2O + Mg_2SiO_4 + MgSiO_3.$$

Upon ordinary ignition, however, this breaking up of the molecule does not always take place; and when it does occur, it is as a rule only partial. In three experiments the serpentines A, C, and D, were strongly ignited over a blast lamp for an hour each, and then treated with strong hydrochloric acid. By this treatment, olivine, if formed, should be decomposed; while enstatite would remain unattacked in the residue. After evaporation to dryness and extraction with weak acid, the insoluble material was boiled with sodium carbonate solution to remove free silica, washed, dried, and weighed. The residues were as follows:

	A	C	D
Per cent	4·32	20·80	39·96

[1] Compt. Rend., vol. lxii, 1866, 661.

The residue from the massive Montville serpentine contained 43·28, and that from the chrysotile 41·34 per cent of magnesia, thus agreeing nearly with enstatite in composition. The picrolite residue was composed of—

MgO	36·31
SiO_2	54·88
R_2O_3	9·26
	100·45

showing it to be an impure enstatite, the impurities being analogous to those of the original mineral. In the last case the splitting up seems to have been practically complete; in the chrysotile it went fully half way, while in the ordinary serpentine it barely began. The conclusion is obvious. When serpentine is simply dehydrated, the molecule $Mg_3Si_2O_7$, decomposable by acids, remains; and this on further heating splits up in accordance with Daubrée's observations. The salt $Mg_3Si_2O_7$ corresponds to certain well known silicic ethers, and is probably a definite compound.

Now, bearing upon the constitution of serpentine, we have several lines of evidence. First, its empirical formula, $H_4Mg_3Si_2O_9$, is well-known and in this all the water is constitutional. Second, upon dehydration it yields the salt $Mg_3Si_2O_7$. Third, a part of the magnesia is less stably combined than the remainder of the base, and is presumably present as —Mg—OH. If one atom of magnesium, or one-third of the total, is thus combined, the excess of one atom of oxygen over the normal orthosilicate ratio in the formula is accounted for, and the conditions imposed by our experimental results are satisfied.

Taking all these considerations into view it seems highly probable that the constitutional formula of serpentine may be written $Mg_2(SiO_4)_2 H_3(MgOH)$. In ultimate structural form this may be interpreted in several ways, any one of which will admit of a linking together of the two orthosilicic groups, after dehydration, with elimination of one oxygen atom, to form the acid group Si_2O_7. Between the several possible structures, however, we are not yet prepared to decide, and further investigation covering other hydro-magnesia silicates is necessary. Bearing in mind the very common derivation of serpentine from olivine, and the obvious relations of both species to chondrodite, the following formulæ are highly suggestive; the first one representing olivine with double its simplest expression:

$Mg_4Si_2O_8$	Olivine.
$Mg_3Si_2O_8(MgF)_2$	Chondrodite.
$Mg_2Si_2O_8H_3(MgOH)$	Serpentine.

In the chondrodite formula of course, the group –Mg–O–Mg– to a certain extent replaces the two univalent MgF groups. Although these formulæ are not absolutely proven, they are at least highly probable; and they conform perfectly to the general working hypothesis that the *more complex silicates are* substitution derivatives of normal salts.

One other formula for serpentine, $MgSi_2O_7(MgOH)_2H_2$, is reconcilable in part with our data. But such a compound ought to be acted upon more strongly by gaseous hydrochloric acid, and two-thirds of the magnesia should be removable. This limit was not even remotely approached in our experiments, although in two cases the one-third limit was definitely exceeded. It is a legitimate question, however, whether there may not be two isomeric serpentine molecules, corresponding to these two formulæ: and this question ought to be kept in view in future investigations.

THE CHLORITE GROUP.

In this interesting but very obscure group of minerals, three species were examined. First, the dark green, broadly foliated, mica-like ripidolite from Westchester, Pennsylvania. This mineral has been repeatedly analyzed, and our results confirm the older data. Second, a dark green, scaly-granular prochlorite, found in excavating the waterworks tunnel in Washington, District of Columbia. Third, leuchtenbergite from the Schischimsk mine near Slatoust, Siberia. The last mineral was kindly sent us by Mr. A. Lösch, of St. Petersburg; but it unfortunately contained inclusions which render our work upon it of little value. The prochlorite was examined microscopically by Mr. Lindgren of the U. S. Geological Survey, who found it to be quite homogeneous. Analyses as follows:

	Ripidolite.	Prochlorite.	Leuchtenbergite.
SiO_2	29·87	25·40	32·27
Al_2O_3	14·48	22·80	16·05
Cr_2O_3	1·56	.....	.....
Fe_2O_3	5·52	2·86	4·26
FeO	1·93	17·77	·28
NiO	·17	.....	.....
MnO	.....	·25	.....
MgO	33·06	19·09	29·75
CaO	.....	.....	6·21
H_2O	13·60	12·21	11·47
F	.....	trace	.....
	100·19	100·38	100·29
H_2O at 105°	.....	·80	·38
" 250°–300°	·95	.15	·21
" 383°–412°	·49	·62	.....
" 498°–527°	.....	·09	.....
" red-heat	11·74	10·55	10·69
" white-heat	·42	.....	·19

Here again we have to deal with water which is plainly constitutional. Hence the suggestion put forward by one of us that the chlorites are essentially micas plus water of crystallization, must be abandoned.[1]

[1] Clarke, Am. Jour. Sci., Nov., 1889.

Upon treatment with dry hydrochloric acid gas at 383°–412°, the three minerals differ considerably. The times of heating and the bases converted into chlorides were as follows:

	Ripidolite.	Prochlorite.	Leuchtenbergite.
Hours heated	19	31	34
MgO removed	13·46	1·54	6·29
R_2O_3 removed	4·24	2·17	·42
SiO_2 removed	·92		

In a second experiment with the ripidolite 58 hours of heating were required before constant weight was attained, and 13·36 per cent of magnesia plus 1·20 of sesquioxides were rendered soluble. In a third experiment the heating lasted 30 hours, and the percentages of MgO and R_2O_3 removed were 11·10 and 3·31 respectively. Even at the ordinary temperature of the laboratory ripidolite was decidedly attacked by the gaseous acid, 4·66 MgO and 3·43 R_2O_3 becoming soluble. In this case the experiment lasted 100 hours. In the case of the prochlorite the result obtained is of very doubtful significance. In a mineral containing so large a proportion of ferrous iron, secondary reactions due to oxidation are possible, and it is not practicable to determine exactly what changes have taken place. The group —Fe—OH might behave like MgOH, and yet subsequent alteration might prevent any estimate of the extent of the reaction.

By digestion with strong, aqueous hydrochloric acid, both ripidolite and prochlorite were completely decomposed. Leuchtenbergite, on the other hand, left an insoluble residue, resembling garnet, which was originally present as an inclusion in the mineral. All of these minerals decompose with aqueous acid more slowly than the serpentines.

By sharp ignition, ripidolite and prochlorite give up in the free state small quantities of silica, which are determinable by extraction with soda solution. The percentages were as follows:

	Ripidolite.	Prochlorite.
SiO_2 liberated	2·98	2·45

These quantities represent only one-tenth of the total silica in the minerals, and have no evident significance in a discussion of the chemical structure.

Although ripidolite is readily decomposable by aqueous hydrochloric acid, it appears to be split up by prolonged ignition into a soluble and an insoluble part. A weighed quantity of the mineral was heated for 9 hours over the blast-lamp, and then digested for 3 days with hydrochloric acid of sp. gr. 1·12. The residue amounted to 48·47 per cent of insoluble matter, from which boiling with sodium carbonate solution

extracted 28·73 of silica belonging to the decomposed silicates. The final undissolved residue, 19·74 per cent, was analyzed, and, treated as an independent substance, gave as follows:

SiO_2	6·32
Sesquioxides	67·81
MgO	25·67
	99·80

If the small quantity of silica here found, only 1·25 per cent of the original material, be neglected as non-essential, the remainder, 18·49 per cent of the ripidolite, has exactly the composition of spinel. Like spinel it is quite insoluble, and in all reasonable probability it may be regarded as that compound. The formation of such a magnesian aluminate, $MgAl_2O_4$, is peculiarly suggestive when we come to consider the structure of the chlorites.

Similar experiments with the prochlorite gave similar but not identical results. After long ignition, 6 hours, and 3 days' digestion with hydrochloric acid, 35·61 per cent of residue remained, of which 18·16 per cent was insoluble in carbonate of soda. This last residue, however, was rich in silica, and therefore could not be spinel. The reaction deserves further study, but the oxidizability of the iron in prochlorite introduces elements of uncertainty which would render it very difficult to interpret the results.

In the case of the leuchtenbergite, little else was done. By means of Thoulet's solution 5·62 per cent of a yellowish garnet were separated from the mineral, which accounts for part, but not all, of the lime found in the analysis. On this species our results are of little value, except as regards the character of the water which it contains, and its comparative behavior towards gaseous HCl.

Now, in order to discuss the formulæ of the three chlorites, we may reject as adventitious the small quantities of water given up at or below 300°. This leaves, as essential water in ripidolite, prochlorite, and leuchtenbergite, 12·65, 11·26, and 10·88 per cent, respectively. Using these figures for water the analyses give the following molecular ratios:

	Ripidolite.	Prochlorite.	Leuchtenbergite.
SiO_2	·498	·423	·538
R_2O_3	·186	·241	·185
RO	·855	·727	·858
H_2O	·703	·626	·604

Hence we have the following empirical formulæ:

Ripidolite	$19R_2O_3$, 86RO, $70H_2O$, $50SiO_2$
Prochlorite	$24R_2O_3$, 73RO, $63H_2O$, $43SiO_2$
Leuchtenbergite	$19R_2O_3$, 86RO, $60H_2O$, $54SiO_2$

And these, reduced to an orthosilicate basis, become—

Ripidolite ..... $R'''_{26}R''_{52}H_{104}(SiO_4)_{50}O_{113}$
Prochlorite ..... $R'''_{26}R''_{72}H_{128}(SiO_4)_{62}O_{139}$
Leuchtenbergite ..... $R'''_{26}R''_{52}H_{104}(SiO_4)_{34}O_{95}$

This excess of oxygen over the orthosilicate ratio can only be interpreted as basic hydroxyl; whence we get—

Ripidolite ..... $R'''_{26}R''_{52}H_{24}(SiO_4)_{50}(OH)_{112}$
Prochlorite ..... $R'''_{26}R''_{72}\ (SiO_4)_{62}(OH)_{177}$
Leuchtenbergite ..... $R'''_{26}R''_{52}H_{24}(SiO_4)_{34}(OH)_{96}$

The last of these formulæ is vitiated by the fact that the mineral analyzed was impure, a fact which appears in the low figure for the hydroxyl, which garnet does not contain. Otherwise it is clear that in general leuchtenbergite and ripidolite agree quite nearly with each other. The question now to be answered is, how shall the hydroxyl be apportioned between the bases?

Taking ripidolite as the mineral of the three which has been most completely examined, we may recall that two concordant experiments with gaseous hydrochloric acid gave 13·36 and 13·46 per cent. of removable magnesia, presumably representing the group MgOH. In mean, these percentages correspond to 34 atoms of magnesia. Regarding this as an index of the MgOH present, we may combine the remainder of the hydroxyl with the sesquioxides to form the univalent group AlH_2O_2, and the ripidolite formula now becomes $(AlH_2O_2)_{26}(MgOH)_{24}R''_{52}H_{27}(SiO_4)_{50}$, with three oxygen atoms unaccounted for and neglectable. Generalizing this expression we have

$$R''_{52}R'_{99}(SiO_4)_{50}$$

or almost exactly, $R''_2(SiO_4)_2R'_4$.

This is an olivine formula, with half of the R'' replaced by R'_2, and is strictly comparable with the formula of serpentine. It will be remembered that von Wartha[1] some time ago advanced the opinion that the chlorites and serpentines form one continuous series of minerals, and his view is by this discussion curiously supported. Furthermore, the probable juxtaposition of the groups AlH_2O_2 and MgOH in ripidolite accounts in great measure for the apparent formation of spinel when the mineral is decomposed by heat.

The ratios found by analysis between H, MgOH, and AlO_2H_2 indicate that ripidolite is probably a mixture of two isomorphous molecules, and the observed data are best satisfied by assuming the compounds $Mg_2(SiO_4)_2(MgOH)_3H$ and $Mg_2(SiO_4)_2(AlO_2H_2)_3H$ in equal proportions. For a mixture of these molecules in the ratio of 1 : 1, the composition is easily calculated, and the results agree well with the analysis. If, in the latter, we recalculate the ferric and chromic oxides to their equivalent in alumina and compute the ferrous oxide as magnesia, reducing

[1] Groth's Zeitschrift, 1887, vol. 13, p. 71.

the summation afterwards to 100 per cent, we get the following direct comparison between analysis and theory:

	Found.	Theory.
SiO_2	31·18	31·09
Al_2O_3	19·87	19·62
MgO	35·74	36·27
H_2O	13·21	12·82
	100·00	100·00

A closer concordance could hardly be expected.

For prochlorite, notwithstanding the uncertainty as to the behavior of the ferrous iron, similar ratios appear. The expression $R'''_{42}R''_{73}(SiO_4)_{42}(OH)_{127}$ reduces to $(AlH_2O_2)_{42}(R''OH)_{31}R''_{42}(SiO_4)_{42}$, in which R''OH is mainly Fe''OH and R'' is almost entirely Mg. This, generalized, becomes $R''_{42}(SiO_4)_{42}R'_{79}$, which is quite nearly the olivine-serpentine type of formula. A mixture of such molecules, in which R' is satisfied by MgOH, FeOH and AlH_2O_2 in the ratio of 1 : 3 : 6, would have the subjoined composition, which is comparable directly with the results of analysis.

	Found.	Calculated.
SiO_2	25·40	24·88
Al_2O_3	22·80	25·37
Fe_2O_3	2·86	
FeO	17·77	17·91
MgO	19·09	19·90
H_2O, essential	11·26	11·94
	99·18	100·00

If the first column were recalculated to 100 per cent, with the ferric iron reduced to its equivalent in aluminum, the agreement would be even closer. In brief, prochlorite seems to have a constitution strictly analogous to that of ripidolite, although, on account of its high proportion of ferrous iron, it behaves differently towards gaseous hydrochloric acid. The leuchtenbergite evidently has a similar structure, but the impurities in the sample analyzed preclude us from discussing this species more in detail. Just as the micas are derived by substitution from normal aluminum salts, so the chlorites are derived from normal magnesium silicates; and in a very curious way the two series seem to approach each other. Thus a compound having the chloritic formula $Mg_2(SiO_4)_2(AlO_2H_2)H_2$, if halved, may be written as if it were a derivative of aluminum orthosilicate analogous to some of the more basic hydro-micas; and the close physical similarity between the two groups is thus remarkably emphasized.

THE MICAS.

In this group only three examples were studied, all of the magnesian or ferro-magnesian class. A. Phlogopite from Burgess, Ontario; the ordinary, slightly brownish, broadly foliated mica, somewhat resembling muscovite. B. Phlogopite from Edwards, St. Lawrence County, New York; the peculiar, non-fluoriferous variety, superficially resembling brucite, described by Penfield and Sperry, whose analysis is thoroughly confirmed by ours. C. A nearly black, broadly foliated iron mica from Port Henry, New York; commonly regarded as a lepidomelane. Analyses as follows:

	Burgess.	Edwards.	Port Henry.
SiO_2	39·66	45·65	34·52
TiO_2	·56	.....	2·70
Al_2O_3	17·00	11·25	13·22
Fe_2O_3	·27	.....	7·39
FeO	·20	·14	22·27
MnO	.....	.....	·41
(CoNi)O	.....	.....	·20
CaO	none.	.....	.....
BaO	·02	.....	.....
MgO	26·49	29·28	5·82
Li_2O	.....	·07	·04
Na_2O	·39	·45	·16
K_2O	9·97	8·53	8·59
H_2O	2·99	5·37	4·29
F	2·24	.....	·24
P_2O_5	trace.	.....	trace.
	100·60	100·23	100·54
Less O	·94	.....	·14
	99·66	.....	100·40

The fractional water determinations gave—

	Burgess.	Edwards.	Port Henry.
H_2O at 105°	·66	.....	·57
" 250°–300°	·35	·73	·45
" red heat	1·98	·73	3·37
" white heat		3·91	

In all the analyses of this investigation, when much iron was found, the total water was determined directly; so that the figures for the higher temperatures do not represent mere loss on ignition. In these micas the percentages of constitutional water, to be used in the discussion of formulæ, are 1·98, 4·64, and 3·37 respectively.

In the Burgess phlogopite numerous inclusions were observed, consisting of slender prisms, and at our request these were examined microscopically by Mr. Waldemar Lindgren. The mica, according to his

examination, is made up of "thin foliæ, under the microscope colorless, dark between crossed nicols; interference figure apparently a cross, not separating into hyperbolas; seemingly uniaxial, but with better instruments it would probably be found to be biaxial with a very small axial angle. Shows excellent asterism, caused by interpositions arranged in three directions cutting each other at an angle of 60°. The inclusions are prisms of a strongly refracting and bi-refracting mineral, so thin as to show brilliant Newton's colors. In spite of the very small thickness, the interference colors are near the white of the first order. Extinction takes place strictly parallel to the prismatic surface. Terminal faces rounded, or unequally developed. Besides prisms there are square or rhomboidal foliæ, probably of the same substance. The inclusions were first observed by G. Rose,[1] who regarded them as kyanite. Rosenbusch describes them again, and determines them as tourmaline.[2] The prisms certainly correspond well in their optical characteristics to this mineral. Kyanite and apatite are excluded from among the possibilities. Probably, in spite of its apparent abundance, the mineral is but a very small fraction of the mica substance." At Mr. Lindgren's suggestion the mica was carefully tested for boron, but none was found. Hence tourmaline, if present, must be in exceedingly small quantities.

On account of the high proportion of titanium in the Port Henry iron mica, this too was examined by Mr. Lindgren, who reports as follows: "It is a dark brown, unusually deep colored, apparently uniaxial biotite, without inclusions, and especially, as far as examined, free from any titanium mineral." Hence the titanium is to be regarded as a constituent of the mica itself.

The action of gaseous hydrochloric acid upon these micas, at 383°—412°, was almost insignificant. The data are subjoined.

	Burgess.	Edwards.	Port Henry.
Hours heated	12	20	33
MgO removed	·40	1·00	trace.
R_2O_3 removed	none.	·21	·44
SiO_2 removed		·13	

In the case of the Port Henry mica some iron was volatilized as chloride. This was estimated; and it was found that the total iron taken out, reckoned as FeO, amounted to only 1·62 per cent. An experiment on the Edwards phlogopite at 498°–527°, lasting 18 hours, gave 1·41 per cent of removable magnesia. This quantity has a possible bearing upon the formula of the mineral.

By aqueous hydrochloric acid all three of the micas were completely decomposed. Hence the Burgess phlogopite could have contained little

[1] Neues Jahrbuch, 1863, p. 91. [2] Physiog. der Mineralien, p. 486.

tourmaline, for that mineral is not soluble in the acid. Moreover, the solubility of the micas prevents us from assuming in either of them an admixture of a muscovite molecule, for muscovite also is insoluble. A careful comparison of the two phlogopites showed that the fluoriferous variety was much more stable towards acids than the rarer non-fluoriferous mineral; a fact which also appears in the action of the gaseous acid upon them. When the two varieties are treated side by side with hydrochloric acid, the Edwards phlogopite decomposes much more rapidly than the Burgess mica.

After very prolonged ignition the Edwards phlogopite and the Port Henry iron mica were still completely decomposable by aqueous hydrochloric acid. There was, therefore, no splitting up of their molecules which could be determined by this method. The Burgess phlogopite, on the other hand, showed a small amount of change. After eight hours of ignition over the blast, treatment with strong hydrochloric acid for three days, and subsequent leaching with soda solution to remove free silica, 2·45 per cent of insoluble residue remained. This, analyzed, gave

SiO_2	30·94
R_2O_3	48·06
MgO	19·01
Alkalies	undet.
	98·01

This agrees quite nearly with the formula $MgAl_2SiO_6$, which is the composition of a possible member of the clintonite group.[1]

Now from the analyses of the micas we get the subjoined molecular ratios; in which titanic oxide is thrown in with the silica, the alkalies are united as potash, and only the essential water, stable above 300°, is retained.

	Burgess.	Edwards.	Port Henry.
SiO_2	·668	·751	·609
R_2O_3	·169	·110	·177
RO	·669	·736	·464
K_2O	·116	·098	·094
H_2O	·110	·258	·187
F	·118	.....	·018

Hence we have the following empirical formulæ:

Burgess..... $17R_2O_3 . 67RO . 12K_2O . 11H_2O . 67SiO_2 . 12F.$
Edwards..... $11R_2O_3 . 74RO . 10K_2O . 26H_2O . 75SiO_2.$
Port Henry .. $18R_2O_3 . 46RO . 9K_2O . 19H_2O . 61SiO_2 . 2F.$

Deducting oxygen equivalent to the fluorine we have

Burgess..... $R'''_{34}R''_{67}K_{24}H_{22}Si_{67}O_{269}F_{12}.$
Edwards..... $R'''_{22}R''_{74}K_{20}H_{52}Si_{75}O_{285}.$
Port Henry ..... $R'''_{36}R''_{46}K_{18}H_{38}Si_{61}O_{249}F_2.$

[1] The minerals prismatine and kornerupine have also this composition.

In all of these micas the silicon and oxygen are present in almost the exact orthosilicate ratio; but in order to discuss the expressions further it is necessary to recall the theory of the mica group which has already been cited. Upon that theory, all these salts should be substitution derivatives of normal aluminum orthosilicate, from which the more definite micas develop as follows:

Normal orthosilicate	$Al_4(SiO_4)_3$.
Muscovite	$Al_3(SiO_4)_3KH_2$.
Normal biotite	$Al_2(SiO_4)_3Mg_3R'_2$.
Normal phlogopite	$Al(SiO_4)_3Mg_3R'_3$.

Applying these formulæ to the expression given above for the Burgess phlogopite, and regarding the fluorine as present in a group —Mg—F, we have for the composition of that mineral:

$$Al(SiO_4)_3Mg_3KH_2 + Al_2(SiO_4)_3Mg_2K(MgF),$$

the two molecules being mixed in the ratio 1:1. Recalculating the original analysis to 100 per cent, uniting TiO_2 with SiO_2, Fe_2O_3 with Al_2O_3, FeO and BaO with MgO, and Na_2O with K_2O, we have this comparison:

	Found.	Calculated.
SiO_2	41·04	41·09
Al_2O_3	17·59	17·46
MgO	27·39	27·39
K_2O	10·62	10·73
H_2O	2·03	2·07
F	2·29	2·17
	100·96	100·91
Less oxygen	·96	·91
	100·00	100·00

The results for the non-fluoriferous phlogopite from Edwards are less satisfactory. Its formula, condensed a little from that given above, is

$$R'''_{22}R''_{71}R'_{72}Si_{75}O_{293},$$

in which the ratio between R''' and Si is 1:3·5 nearly. But in this mica three atoms of magnesia are removable by gaseous HCl, corresponding to 3MgOH. If we assume that this represents a small admixture of a foliated serpentine, and deduct proportionally, there remains

$$Al_{22}Mg_{65}H_{40}K_{20}Si_{69}O_{266},$$

which is very nearly $Al(SiO_4)_3Mg_3KH_2$, or normal phlogopite. At first, as the mineral occurs in a talc mine, we suspected that its anomalies might be due to intermingled talc; but its complete decomposability by hydrochloric acid showed that supposition to be incorrect. If the mica theory is correct, this mineral must contain a small amount of impurity; and a serpentinous or chloritic molecule is the most probable admixture.

In the Port Henry mica the ratios are perfectly simple. The formula,

$R'''_{36}R''_{46}K_{18}H_{38}(SiO_4)_{81}O_3F_2$, if we neglect the small amounts of fluorine and excessive oxygen, reduces easily to a mixture of the three typical molecules:

$$Al_3(SiO_4)_3Fe''_2KH,$$
$$Fe'''_2(SiO_4)_3Fe''_2KH,$$
$$Al(SiO_4)_3Mg_3KH_2,$$

in the ratio 2:1:1. This compares well with the analysis, reduced as usual, thus:

	Found.	Calculated.
SiO	37·02	37·41
Al_2O_3	13·39	13·34
Fe_2O_3	7·80	5·34
FeO	22·56	22·51
MgO	6·30	6·26
K_2O	9·08	9·79
H_2O	3·75	3·35
	100·00	100·00

Here the theoretical water is too low and the potash too high; both outside the allowable range of error. Their reciprocal replacements explain the slight discordance only in part; and the nature of the mineral suggests a small excess of water due to incipient alteration. Altogether the agreement between analysis and theory is remarkably close.

THE VERMICULITES.

Of this interesting group two examples were studied; the well known typical jefferisite from Westchester, Pennsylvania, and the kerrite from near Franklin, Macon County, North Carolina. The latter, presented to us by Prof. F. A. Genth, was part of his original sample, and the analysis agrees well with Chatard's. Analyses as follows, on *air-dried* material.

	Jefferisite.	Kerrite.
SiO_2	34·20	38·13
Al_2O_3	16·58	11·22
Fe_2O_3	7·41	2·28
FeO	1·13	·18
NiO	.....	·48
CoO	.....	trace
MgO	20·41	27·39
H_2O (ignition)	21·14	20·47
	100·87	100·15
H_2O over H_2SO_4	10·56	9·62
H_2O at 105°	.....	·24
H_2O at 250°–300°	4·20	4·10
H_2O at red heat	6·18	6·27
H_2O at white heat	·20	·24

Here the water falls into three sharply defined parts: one, lost by drying over sulphuric acid, very loosely held; a second, water of crystallization, lost below 300°; and the third, constitutional water.

By dry hydrochloric acid gas the minerals were little affected. The data are as follows for 383°–412°:

	Jefferisite.	Kerrite.
Hours heated	32	32
MgO removed	3·98	3·15
R_2O_3 removed	1·38	·09

By aqueous hydrochloric acid both of the vermiculites were easily and completely decomposed. By ignition, however, with fusion in the case of the kerrite, they were split up into soluble and insoluble portions. In the kerrite, after fusion, only 10·64 per cent of magnesia and 3·75 of sesquioxides were removable by aqueous hydrochloric acid, but nothing more could be determined for want of material. The jefferisite, after strong ignition and subsequent digestion with the acid for 3 days, gave 51·08 per cent of insoluble residue. From this, soda solution extracted 21·54 of silica, leaving 29·54 per cent of an undecomposed silicate. This, analyzed independently, contained

SiO_2	45·08
Al_2O_3	22·82
Fe_2O_3	10·01
MgO	21·48
	99·39

Hence the ratios $SiO_2 : R_2O_3 : MgO = 75 : 29 : 54$; which correspond nearly to a mixture of Al_2SiO_5 with $Mg_2Si_2O_6$. As to the real nature of this residue, we can only offer the foregoing suggestion as a plausibility. Positive knowledge is lacking. The vermiculites, however, are alteration derivatives of the micas; and by their metamorphosis kyanite, fibrolite, or andalusite might, perhaps, be generated in nature. Geologically, the suggestion is worthy of consideration.

Now, from the two analyses we get the subjoined molecular ratios:

	Jefferisite.	Kerrite.
SiO_2	·570	·635
R_2O_3	·209	·124
RO	·526	·694
H_2O, over H_2SO_4	·587	·524
H_2O, 250°–300°	·233	·226
H_2O, constitutional	·355	·363

Hence the empirical formulæ

Jefferisite	$R'''_{42}R''_{83}H_{70}Si_{57}O_{265}+82H_2O$
Kerrite	$R'''_{24}R''_{69}H_{72}Si_{63}O_{267}+75H_2O$

For the jefferisite gaseous hydrochloric acid removed 10 atoms of magnesia, and from the kerrite 8 atoms. Taking this, hypothetically, as MgOH, we have

Jefferisite ..... $R'''_{42}R''_{43}(MgOH)_{10}H_{60}(SiO_4)_{57}O_{27}+82H_2O$
Kerrite ..... $R'''_{24}R''_{61}(MgOH)_8H_{64}(SiO_4)_{61}O_7+75H_2O$

The small excess of oxygen in these expressions needs to be accounted for. To regard it as forming the group AlO, however, is impracticable; for then the residual aluminum atoms would be less than one-third the silicic groups, which is inadmissible under the mica theory. The simplest interpretation is as follows: In the clintonite group the general formula

$$R''' \begin{cases} O \\ O \\ SiO_4 \end{cases} > R'' = R'_3$$

seems to apply. If we treat the excess of oxygen in the two vermiculites as pertaining to molecules of this order, the composition of both minerals reduces to very simple terms; one term being a normal hydromica. In the jefferisite we have approximately $AlO_2MgSiO_4R'_3.3H_2O + Al_2(SiO_4)_3Mg_2H_2.3H_2O$; or a mixture in equal ratios of a hydro-clintonite and a hydro-biotite, the alkalies being replaced by hydrogen, and R′ being in part, about one-third, MgOH. The greatest uncertainty is in the loosely combined water, which is probably analogous to the water in laumontite. Two-thirds of the $3H_2O$ is of this type; the remaining one molecule being given off below 300°. Dried at 100° the salts become monohydrated. Reducing the bases of the analysis to terms of alumina and magnesia we get the following comparison with the formula:

	Found.	Calculated.
SiO_2	34·97	34·00
Al_2O_3	21·91	21·67
MgO	21·51	22·67
H_2O constitutional	6·52	6·37
H_2O, 250°–300°	4·30	5·10
H_2O, over H_2SO_4	10·79	10·19
	100·00	100·00

The concordance here is less perfect than in the previous cases, but for obvious reasons. First, the uncertainty in the water has already been mentioned. Secondly, the actual ratio between the clintonite and biotite molecules, as deduced from the empirical formula, is not 1 : 1 but 13 : 15. Finally, the observed MgOH is a little less than one-third R'_3. Still, considering the character of the mineral, the agreement between analysis and theory is as close as could be expected.

For kerrite, uniting the univalent factors, the formula becomes

$$R'''_{24}R''_{61}R'_{72}(SiO_4)_{63}O_7 . 75H_2O,$$

This, very nearly, is equivalent to

$$AlO_2MgSiO_4R'_3 . 3H_2O + Al(SiO_4)_3Mg_3H_2 . 3H_2O,$$

commingled in the ratio of 1:5, with two-thirds of R'_3 being MgOH. The second term in this mixture is a hydrous phlogopite; and here again we have trihydration, with two molecules of water loosely held and the third more firmly combined. In this case we may compare the analysis, reduced to alumino-magnesian form and 100 per cent, both with the formula given above and with that of the hydrous phlogopite taken separately.

	Found.	Calculated.	
		As given.	As phlogopite.
SiO_2	38·51	38·33	41·66
Al_2O_3	12·79	12·38	11·84
MgO	28·03	29·12	27·77
H_2O, constitutional	6·61	6·55	6·25
H_2O, at 250°–300°	4·35	4·37	4·16
H_2O, over H_2SO_4	9·72	8·75	8·32
	100·00	100·00	100·00

This comparison, which is in the main satisfactory, makes it perfectly clear that kerrite is essentially a trihydrated phlogopite, with the alkalies replaced by hydrogen. The analogies between kerrite and jefferisite are perfectly clear, and both minerals become monohydrated by exposure over sulphuric acid. It is our intention to examine several other vermiculites in the near future, and we believe that all of them will be easy to interpret with the aid of the evidence already gained.

FINAL CONSIDERATIONS.

In the foregoing pages we have shown conclusively that gaseous and aqueous hydrochloric acid differ widely in their action upon magnesian silicates. We have also endeavored to show that in this group of minerals, the gaseous acid attacks only that part of the magnesium which is present as the univalent group —Mg—OH; and although the proof is far from complete, the evidence in favor of our view appears to be cumulative. In the first place olivine, which can not contain hydroxyl, is almost unattacked by the gas in the range of temperatures studied. Secondly, serpentine, which must contain MgOH, is attacked proportionally to the excess of oxygen over the orthosilicate ratio. The results, to be sure, are only approximations to quantitative accuracy, but they are uniform enough to warrant our conclusion. Finally, ripidolite behaves like serpentine, and gives an analogous formula; while the micas, which presumably contain little or no hydroxylated magnesia, are but slightly affected. All the evidence, so far, converges to

the one conclusion; which has at least the status of a legitimate working hypothesis. All the hydrous silicates so far examined are not alike in their behavior towards the reagent, but only those are attacked by it in which there are strong reasons for assuming the presence of the basic MgOH.

In the course of the investigation certain collateral questions have arisen which have been the subject of experiment. For instance, in the action of gaseous hydrochloric acid upon silicates may not insoluble oxychlorides be formed, which would escape notice in the analysis of the soluble portion? To answer this question the residues were in several cases examined, and found to be practically free from chlorine. Traces only of chlorine were retained, insufficient to modify our ratios. Furthermore, precipitated and ignited magnesium oxide, heated at 498°–527° in gaseous hydrochloric acid, was almost quantitatively converted into chloride, showing the stability of the latter in a stream of the dry gas; 94·13 per cent of the required chlorine was taken up by the oxide, so that the possible formation of oxychlorides in our experiments may be fairly left out of account.

Similar experiments with brucite, however, gave apparently anomalous results. The mineral examined was typical material from Texas, Lancaster County, Pennsylvania, which was first analyzed and subjected to dehydration estimations. The data are as follows:

MgO	67·97
FeO	undet.
MnO	0·97
Fe_2O_3	0·39
H_2O	30·81
	100·14
Water lost at 105°	0·18
" " 250°	0·46
" " 383°–412°, 2 hours	7·57
" " " 3 " more	19·37
" " " 2 " "	0·06
" " 498°–527°, 1 "	0·23
" " " 1 " more	none
" " full ignition	2·94

The greater part of the water, therefore, nine-tenths of it, is lost at about 400° C., but is given off somewhat slowly.

Heated for 28 hours to 383°–412° in dry hydrochloric acid gas, constant weight was not attained; but at this point the experiment was stopped, and only 10·33 per cent of the magnesia had been converted into chloride, or a little less than one-seventh of the total amount. Several other experiments, at temperatures ranging from 200° to 500° gave similar results, all low, and in no case was more than one-fifth of the required chlorine absorbed. At the higher temperature, 498° to 527°, the reaction went farthest, and the absorption of chlorine was still going on at a very slow rate. In this case, the brucite must have

become almost dehydrated; but the oxide so formed was different in its behavior from the precipitated oxide previously examined. The difference may have been due to physical causes, such as a different degree of compactness in the material; but it is doubtful whether that supposition would fully account for the anomaly. Probably magnesium hydroxide, like other hydroxides investigated by Carnelley and Walker,[1] undergoes progressive dehydration through a series of stages; each step being attended by a polymerization of the residue. An oxide so formed might conceivably be more stable than the oxide with which we previously worked; at all events, the two are not necessarily identical. As regards the bearing of these data upon our silicate work, we can hardly offer satisfactory conclusions. Still, magnesium saturated by hydroxyl is quite differently combined from magnesium which is but half saturated with that radicle, and in the mixed union in a silicate, the polymerization attending dehydration above referred to could hardly occur. We are inclined to believe, on the whole, that MgOH in a silicate has a lower order of stability towards gaseous HCl than the compound $Mg(OH)_2$; but this point remains to be proved. We hope to continue this investigation among other silicates; and we feel confident that the data so far obtained have value quite independently of our conclusions.

[1] Jour. Chem. Soc., 1888, vol. 53, p. 59.

THE RELATIVE ABUNDANCE OF THE CHEMICAL ELEMENTS.

By F. W. Clarke.

In the crust of the earth, with its liquid and gaseous envelopes, about seventy chemical elements are at present recognized. Others, as yet unknown, are indicated by gaps in the periodic system and will probably be discovered in the future. Some of the elements are quite plentiful, some are exceedingly rare, and in any thorough discussion of their nature and relations this comparative abundance or scarcity should be taken into account. Even though the full meaning of the facts may not be discoverable for many years to come, it is worth while to put them into something like systematic order.

In its larger aspects the general problem is at present unsolvable, for the reason that we know nothing of the earth's interior. Its surface only is within our certain reach, and from the composition of that we must draw nearly all our conclusions. For that which lies below the crust we must be content with inferences based upon the scantiest of data. Of the crust itself the average composition is easily computable, and the calculation gives results which are in some respects surprising.

In order to have a definite mass of matter under consideration, we may assume for the earth's *known* crust a thickness of ten miles below sea-level. The volume of that crust, including the mean elevation of the continents above the sea, is 1,935,000,000 cubic miles. Of this amount 302,000,000 cubic miles are ocean and 1,633,000,000 are solid matter. The mass of the atmosphere is equivalent to that of 1,268,000 cubic miles of water, the unit of density. For these data, which cover all the terrestrial matter accessible to us, I am indebted to Mr. R. S. Woodward, of the U. S. Geological Survey, and from them the relative masses of solid crust, ocean, and atmosphere can be determined within narrow limits of uncertainty. To sea water we may assign a density of 1·03, which is a trifle too high, and to the solid rocks, a specific gravity not lower in average than 2·5, nor much higher than 2·7. With these

values we can get the following expression for the percentage composition of the known matter of the globe:

Per cent.	Density of crust 2·5.	Density of crust 2·7.
Atmosphere	·03	·03
Ocean	7·08	6·58
Solid crust	92·89	93·39
	100·00	100·00

In short, we may regard the earth's crust, to a depth of ten miles, as composed essentially of 93 per cent. solid and 7 per cent. liquid matter, treating the atmosphere as a small correction to be applied later. More elaborate estimations are unnecessary. Since the known nitrogen of the earth is mainly in the atmosphere, its relative scarcity as an element is at once curiously manifest. It cannot possibly exceed 0·025 of 1 per cent. of the total.

For the composition of the ocean, the data given by Dittmar in the Reports of the Challenger Expedition are perhaps the best available. The maximum salinity he puts at 37·37 grammes of salts in the kilogramme of water, and by taking this figure instead of a lower value we can make an allowance for saline masses inclosed in the solid crust, which would not otherwise appear in the final averages. Combining this datum with Dittmar's statement of the average composition of the ocean salts, we get the second of the subjoined columns. The traces of other elements, not named here, which have been found by various observers in sea water, are too small to be considered.

Composition of salts.		Composition of ocean.	
$NaCl$	77·76	O	85·79
$MgCl_2$	10·88	H	10·67
$MgSO_4$	4·74	Cl	2·07
$CaSO_4$	3·60	Na	1·14
K_2SO_4	2·46	Mg	·14
$MgBr_2$	·22	Ca	·05
$CaCO_3$	·34	K	·04
	100·00	S	·09
		Br	·008
		C	·002
			100.000

Dissolved gases need not be taken into account, and no other constituent of the ocean can reach 0·001 of 1 per cent.

In the case of the solid crust of the earth the problem of ascertaining its mean composition is far less simple; for the crust is not a homogeneous body, but is made up, so to speak, of shreds and patches—of old crystalline rocks, of volcanic outflows, and of all manner of deposit

of sedimentary origin. It is veined and seamed with diverse minerals, it incloses pockets of various materials, and upon its surface are quantities of organic matter and great bodies of fresh water. At first sight it would seem to be impossible to determine the average composition of such a mass, and yet, upon consideration, the question is not seriously complicated. In a crust ten miles thick a section having the superficial area of the United States represents only about 1·5 per cent of the total; so that all veins, pockets, patches, organic substances, etc., become insignificant in comparison with the whole mass, and even the lakes and rivers are neglectable quantities. On any attempt to compute their percentages they vanish into the dim recesses of the remoter decimals. Discarding these trivial constituents the question becomes one of the mean composition of the dominant rock material, and in that form it is comparatively simple.

In the first place, we may assume that the volcanic and crystalline rocks represent pretty closely the general composition of the whole crust; for from them the sedimentary rocks have been formed, and the latter differ from the parent formations only in the carbon which they have taken up from the air and in the loss of saline constituents which have been leached out to the ocean. For this gain and loss, respectively, approximate corrections are possible.

In the second place, we must regard the original rock matter, volcanic and crystalline, as being in a large sense fairly homogeneous. However greatly these formations may vary locally, they should average pretty much alike all over the world when sufficiently large areas are considered. This assumption can be tested in the light of evidence, as follows: We may average together great numbers of analyses, grouped in various ways, and so determine whether the results are sensibly constant. This has been done in the subjoined table, minor and occasional constituents being temporarily omitted, to be separately considered later.

Table of analyses of rocks.

A. The mean of 82 analyses of volcanic rocks from the Western Territories of the United States, published in Clarence King's Survey of the Fortieth Parallel.

B. 64 analyses of rocks from the Yellowstone Park, taken from the laboratory records of the U. S. Geological Survey.

C. 54 analyses of volcanic rocks collected in northern California; also from the Survey records.

D. 39 analyses of eruptive rocks from various localities in the Western United States, taken from the Survey records.

E. 80 crystalline and archean rocks from all parts of the United States. Of these analyses 50 were taken from the Survey records, 23 from the 40th Parallel Report, and 7 from the report of the New Hampshire Survey, vol. 3.

F. 75 analyses of European volcanic and crystalline rocks, taken at random from five recent volumes of the Neues Jahrbuch.

G. 486 miscellaneous plutonic rocks, analyzed between 1879 and 1883, and collected by Roth in his "Beiträge zur Petrographie der plutonischen Gesteine."

H. The mean of the foregoing 880 analyses.

	A.	B.	C.	D.	E.	F.	G.	H.
SiO_2	61·89	61·89	60·49	60·66	60·50	59·80	56·75	58·59
Al_2O_3	15·71	15·73	16·08	15·46	14·30	14·65	14·90	15·04
Fe_2O_3	1·81	3·18	2·47	2·74	3·35	4.99	4·58	3·94
FeO	3·65	2·40	2·86	2·27	4·31	2·92	3·71	3·48
CaO	4·51	4·58	6·15	4·71	3·52	5·19	5·79	5·29
MgO	2·40	3·08	4·31	3·35	5·00	3·45	5·22	4·49
K_2O	3·54	2·70	1·80	3·97	2·52	3·06	2·90	2·90
Na_2O	3·28	3·70	3·31	3·54	2·49	2·98	3·24	3·20
H_2O	1·69	1·59	1·12	·97	2·53	2·09	2·12	1·96
	98·48	98·85	98·59	97·67	98·52	99·13	99·21	98·89

That these means are remarkably concordant, especially as regards the columns A to F, is at once evident; but a reduction to elementary form renders the agreement even more striking.

Table of analyses of rocks—Elementary substances.

	A.	B.	C.	D.	E.	F.	G.	H.
Si	28·88	28·88	28·23	28·31	28·23	27·91	26·50	27·34
Al	8·31	8·32	8·51	8·18	7·57	7·75	7·89	7·96
Fe	4·11	4·09	3·96	3·68	5·71	5·77	6·09	5·47
Ca	3·22	3·27	4·39	3·37	2·51	3·71	4·13	3·78
Mg	1·44	1·85	2·58	2·01	3·00	2·07	3·13	2·69
K	2.94	2·24	1·49	3·29	2·09	2·54	2·41	2·41
Na	2·43	2·74	2·46	2·63	1·85	2·21	2·56	2·37
H	·19	·18	·12	·11	·28	·23	·24	·22
O	46·96	47·28	46·85	46·09	47·28	46·94	46·26	46·65
	98·48	98·85	98·59	97·67	98·52	99·13	99·21	98·89

The thesis that the crust of the earth is fairly homogeneous in composition is thus sustained by positive evidence. The variations in the foregoing table are as small as could reasonably be expected.

So far, however, only nine of the rock-forming elements are accounted for. The proportions of the others are less easily computable, although in some cases fair estimates can be made. In certain directions very many of the analyses considered, especially in the columns A and G, were incomplete, constituents like titanium, manganese, phosphorus, etc., having been ignored as not essential to the purpose of the analyst. These substances appear in part, therefore, as impurities in the silica and alumina, rendering the latter a trifle too high.

For several of the less frequently determined elements the laboratory records of the U. S. Geological Survey furnish data. In 211 analyses of volcanic and crystalline rocks there recorded, titanium, manganese, and phosphorus were determined in a great majority of cases, and other elements appear frequently enough to prove something as to their relative abundance. Taking these 211 analyses all together,

they show the following mean percentages for the constituents in question:

TiO_2	0·55
P_2O_5	·22
MnO	·10
CO_2	·37
S	·034
Cr_2O_3	·021
BaO	·033
SrO	·009
Cl	·012
Li_2O	·011

All of these figures, obviously, are *under*-estimates, for the determinations were not made in all cases. Furthermore, the rocks analyzed were varied enough in origin, locality, and character, to avoid any cumulative error due to the peculiarities of any one formation or area. The value for titanic oxide includes whatever zirconia may have been present in the various rock samples, but although the latter base is widely diffused, its proportion can not be very high. Titanium, therefore, must be regarded as more abundant than phosphorus, manganese, or sulphur—a result hardly to have been expected. This conclusion, however, is borne out by evidence from other sources. Titanium is rarely absent from the older rocks; it is almost universally present in soils and clays, and it is often concentrated in great quantities in beds of iron ore. Having no very striking characteristics and but little commercial importance, it is easily overlooked, and so it has a popular reputation for scarcity which it does not deserve. Among all the elements it probably ranks tenth or eleventh in point of absolute abundance and is rare only as regards obvious concentrations. In the solar spectrum it is one of the most conspicuous of substances.

For phosphoric acid and manganese the data given are probably not far out of the way, but in the case of carbon the estimation is more troublesome. The percentage of CO_2 in volcanic and crystalline rocks, 0·37, is doubtless untrustworthy, for the reason that surface rocks are mainly represented, in many of which alteration may have begun. The figure, however, may be used as an offset for the undeterminable carbon existing in coal, shales, petroleum, etc. As regards the limestones, rough estimates of their quantity must suffice, and we may provisionally accept that of T. Mellard Reade as given in his essay on "Chemical Denudation in Relation to Geological Time." According to Reade, the existing bodies of limestone are equivalent to a layer of the rock 528 feet thick and completely enveloping the globe. This is approximately 1 per cent of the crust under consideration, and represents 0·44 per cent of CO_2. To this we may add the 0·37 per cent given above, making 0·81 per cent in all—an estimate which can hardly be too low.

In the case of sulphur, the figure given, 0·034 per cent, is surely

much too low; for sulphur is abundant both in sulphates and in sulphides, and iron pyrites especially is widely diffused. The absolute proportion of this element seems to be hardly determinable. It should be at least 0·05 and probably not over 0·10 per cent. For chlorine, chromium, barium, and strontium the figures are minima, but can not be very largely increased. The value for lithia is probably not far out of the way, for that oxide is almost universally present in minute traces in the older crystalline rocks, although it is rarely estimated in ordinary analyses.

Now, taking the mean of 880 analyses as cited in column H of the table, we may insert in it the additional values so far determined, but with certain qualifications. In about half of the analyses TiO_2, P_2O_5, and Cr_2O_3 were not estimated, but their amounts appear in the figures for silica and alumina. The silica, then, may be reduced by about one-fourth the percentage of the titanic oxide, and the alumina by the other fourth, plus half the values assigned to P_2O_5 and Cr_2O_3. Making these corrections, reducing to elementary form, and recalculating to 100 per cent, we get a rough approximation to the mean composition of the solid crust of the earth. To this approximation the other unestimated elements may be regarded as future corrections of very small amount. Combining this result with the mean composition of the ocean, and including 0·02 per cent for the nitrogen of the air, we get the final column to illustrate the abundance of the elements so far as at present known. Quantities less than 0·01 per cent are left out of consideration.

	Solid crust, 93 per cent.	Ocean, 7 per cent.	Mean, including air.
Oxygen	47·29	85·79	49·98
Silicon	27·21	.....	25·30
Aluminum	7·81	.....	7·26
Iron	5·46	.....	5·08
Calcium	3·77	·05	3·51
Magnesium	2·68	·14	2·50
Sodium	2·36	1·14	2·28
Potassium	2·40	·04	2·23
Hydrogen	·21	10·67	·94
Titanium	·33	.....	·30
Carbon	·22	·002	·21
Chlorine	·01	2·07	·15
Bromine	.....	·008	
Phosphorus	·10	.....	·09
Manganese	·08	.....	·07
Sulphur	·03+	·09	·04+
Barium	·03	.....	·03
Nitrogen	.....	.....	·02
Chromium	·01	.....	·01
	100·00	100·000	100·00

Nineteen of the elements are here provided for with very varying degrees of probability, although their order in the last column is pre-

sumably correct. The uncertainty may reach 1 per cent in the cases of silicon and iron, one-half as much with aluminum and oxygen, and is proportionally less for the other elements specified. The remaining elements, more than fifty in number, can hardly aggregate over 1 per cent altogether, and not one of them could pass 0·05 per cent in relative quantity. Some of them may be briefly considered in detail, as follows:

Fluorine.—Abundant in fluor-spar and apatite and present in many rocks as a constituent of topaz or mica. If the phosphorus in the foregoing estimate, 0·09 per cent, represents mainly apatite, the proportional amount of fluorine would be 0·02 to 0·03, the minimum assignable value.

Glucinum.—Widely distributed as beryl and easily overlooked in small traces. If determined, it would appear as a correction to the alumina.

Boron.—Comparatively abundant in tourmaline and datolite and conspicuous in certain volcanic waters; difficult to estimate.

The Cerium group.—According to Cross and Iddings, allanite is a widespread constituent of rocks. The same is true of monazite, as shown by Derby. These elements, together with thorium, zirconium, and the yttrium groups, would appear as corrections to alumina.

Nickel.—Frequent in rocks composed of or derived from olivine. Less than 0·01 per cent.

The metallic acids—stannic, molybdic, tungstic, columbic, and tantalic.—These, if determined, would form corrections to silica. The same is true to some extent of barium when present in rocks as sulphate.

The heavy metals.—Widely distributed in rocks, according to Sanberger's researches, but in very small quantities.

In the larger items, say from oxygen down to the alkaline metals, the estimates here given do not differ very widely from others which have been long current in chemical and geological literature. They rest, however, upon fuller evidence, and the discussion is, perhaps, more complete. In the smaller items the new results display the greatest novelty, and future modifications are most likely. The comparative rarity of carbon and sulphur is, to say the least, surprising.

On the theoretical side the results attained are not easy to interpret. That nine of the chemical elements should constitute, at the lowest estimate, 98 per cent of all known terrestrial matter is somewhat startling and difficult to comprehend. Are the other elements concentrated in the interior of our planet? On this point there is a little positive evidence.

The mean density of the earth, 5·5 to 5·6, is more than double that of the rocky crust, and the difference may be accounted for as a result of pressure, or by supposing that as the globe cooled the heavier elements accumulated toward the center. Both suppositions may be true in

part, but less weight is to be placed upon the second, for the following reason: A mixture of the elements in equal proportions, in the free state and as they behave at the earth's surface, would have a specific gravity of about 7·3. In combination the density would be greater because of condensation, and below the surface it would also be increased by pressure. Hence it seems clear, since the density of the earth is only 5·5, that in the planet as a whole the lighter elements must very considerably exceed in quantity the heavier ones. Twenty-nine of the known elements have densities below 5·5, and forty exceed that figure, iron being the only one of the heavier group which is at all abundant. The greater part of the earth's mass is almost certainly to be found among the twenty-nine lighter elements. The others may be more plentiful at the center of the globe than upon its surface, but few beside iron can be dominant constituents. This evidence seems to be clear, even though it is not proof positive. Whether the composition of meteorites can be made to shed any light upon this question is very doubtful, although some interesting analogies might be discovered. The resemblance between meteoric stones and volcanic rocks is noteworthy, and the richness of meteorites in metallic iron and nickel is suggestive. The earth, below its crust, may be like a huge meteorite in composition, with the stony part predominating.

An attempt was made in the course of this investigation to represent the relative abundance of the elements by a curve, taking their atomic weights for one set of ordinates. It was hoped that some sort of periodicity might be evident, but no such regularity appeared. No definite connection with the periodic law seemed to be traceable. And yet certain other regularities are worth noticing. All of the abundant elements are low in the scale of atomic weights, reaching a maximum at 56 in iron. Above 56 the elements are comparatively rare, and only two of them, barium and strontium, appear in my estimates. Below oxygen, hydrogen alone approaches 1 per cent, while between oxygen and iron only scandium and vanadium are of neglectable rarity. Furthermore, in several elementary groups abundance diminishes with increase of atomic weight. This is plainly seen in the series potassium, rubidium, and cæsium; in sulphur, selenium, and tellurium; in chlorine, bromine, and iodine; in arsenic, antimony, bismuth, etc. The regularity is not certainly invariable, but it occurs often enough to be suggestive. Again, in the distribution of the elements with regard to each other there are indications of something like system. Closely allied elements commonly occur together, so that the presence of one implies the presence of the others; for example, cobalt and nickel are almost always associated; vanadium is rarely found unaccompanied by at least some phosphorus; nearly all native gold contains silver; no member of the platinum group ever occurs singly, and so on. Still another kind of order seems to appear among the compounds formed in the earth's crust, and elements of high atomic weight appear to seek each other. Thus

in the series oxygen, sulphur, selenium, tellurium, the commonest oxides range from iron downward; the commonest sulphides range from iron upward, while the selenides and tellurides are preferably formed by the heavier elements silver, gold, lead, and bismuth. So also the phosphates are most abundant below iron, where arsenates are of extreme rarity; while above iron the arsenates occur more frequently. These relations can not be meaningless, but what they mean is not yet clear.

Perhaps a part of the difficulty in tracing periodic relations in the comparative abundance of the elements arises from the fact that our field of view is limited to the earth and does not include the whole solar system. Indeed, several writers, reasoning on the broader basis of the nebular hypothesis and noting the low densities of the outer planets, have argued that the latter may contain the lighter elements mainly, while the heavier substances are concentrated at the original nucleus, the sun. Along this line, however, close reasoning is impossible, partly because evidence is lacking and partly because the conditions of temperature and pressure differ so widely between the sun and the other heavenly bodies. As thus attacked, the problem becomes one of enormous complexity, and even the solar spectrum gives us no conclusive evidence. That oxygen and silicon are not conspicuous in the sun's atmosphere we may admit, but that nonvolatile silica is absent from the solar body is by no means certain. We may assume that compounds can exist nowhere in the sun, but the assumption is unprovable. As to the composition of the outer planets we know practically nothing. How far they may differ from each other, from the earth, and from the sun is as yet a matter of pure conjecture.

If, despite Mendelejeff's recent demurrer, we assume that the elements have been evolved from one primordial form of matter, their relative abundance becomes suggestive. Starting from the original "protyle," as Crookes has called it, the process of evolution seems to have gone on slowly until oxygen was reached. Below oxygen we have the elements hydrogen, lithium, glucinum, boron, carbon, and nitrogen, between which no remarkably strong affinities occur. With the appearance of oxygen strong affinities come into play, the process of evolution exhibits its greatest energy, and the elements forming stable oxides are the most rapidly developed and in the largest amounts. On this supposition, vague as it is, the scarcity of the elements above iron becomes somewhat intelligible; but the theory does not account for everything and is to be regarded as merely tentative. It is legitimate only so long as its purely speculative character is kept clearly in view. If, however, the evolution of the elements is admitted, it is clear that the later stages of the process must have been seriously conditioned by the chemical affinities developed at first.

ON THE OCCURRENCE OF NITROGEN IN URANINITE AND ON THE COMPOSITION OF URANINITE IN GENERAL.[1]

By W. F. Hillebrand.

GENERAL INTRODUCTORY REMARKS.

When the work which is described in the following pages was commenced in 1888 it was simply as an analysis of a fragment of a large crystal of uraninite from Glastonbury, Connecticut, without thought of further extension. Thoria had been found in it and quantitative analysis was made in order to learn if possible whether this belonged to the uraninite or was due to an accidental admixture of thorium silicate as found by Penfield[2] to be the case, at least in part, for the thoria in monazite from Portland, Connecticut, and Amelia County, Virginia. It was hereby established that the 10 per cent of thoriafound was a constituent of the uraninite, and the unexpected discovery was made that no formula in the slightest degree corresponding to that found by Comstock[3] for the Branchville, Connecticut, uraninite and by Blomstrand[4] for the Norwegian and Bohemian varieties could be assigned to this from Glastonbury. The hitherto unanalyzed uraninite formerly found at Black Hawk, Colorado, was then examined and was likewise not referable to the orthouranate formula of Blomstrand. No thoria was found in it, but instead about 7 per cent of zirconia. In both cases about 60 per cent of UO_2 had been found, whereas the highest percentage given by any other analyst was in the neighborhood of 54 per cent for the Branchville variety. My own experiments had shown such extraordinary variations in the percentages of UO_2 found by the ordinary method of decomposing with sulphuric acid in sealed tubes filled with carbonic acid and titrating with potassium permanganate that a reexamination of the Branchville mineral seemed desirable.

Profs. Brush and Dana, of New Haven, very kindly placed at my disposal the remainder of their material from that locality, it being the same lot from which Comstock had selected his sample for analysis. While different samples showed different amounts of UO_2, the results were from 10 to 18 per cent higher than Comstock's, and moreover, about 7 per cent of thoria was found which had been entirely overlooked

[1] An abstract of this paper was published in the Am. Jour. Sci., 1890, vol. 40, p. 384.
[2] Am. Jour. Sci., [3], 1882, vol. 24. p. 250.
[3] Am. Jour. Sci. [3[, 1880, vol. 19, p. 220.
[4] Geol. För. Förh., 1884, vol. 7, p. 59; and Jour. prakt. Chem., 1884, vol. 29, p. 191.

by him. This latter, as in the Glastonbury mineral, was not referable to any thorium silicate, nor to a phosphate, but belonged to the uraninite. Comstock's formula, $3RO_2+2RO_3$, for the Branchville uraninite was of course hereby invalidated. Of North American occurrences of this mineral it only remained to examine that from North Carolina. From the Black Hills, Dakota, where it has been reported to occur, I have been unable to procure specimens, and the same can be said of the at that time unknown Llano County, Texas, locality, whence a closely allied mineral, nivenite, has recently been described by Hidden and Mackintosh.[1] Owing to its evident alteration it was not expected that light would be thrown on the question of original composition by an examination of the North Carolina material, but the presence or absence of thoria could be ascertained, as it was affirmatively by finding that and other earths.

In view of what had thus been learned regarding the uraninites of this country it seemed advisable to reexamine the European varieties. Specimens from Przibram, Joachimsthal, and Johanngeorgenstadt contained no rare earths whatever, but they were so contaminated with carbonates and sulphides and some combination of vanadium that it seemed for the present useless to attempt an estimation of UO_2 in them. Through Prof. F. W. Clarke, of the U. S. Geological Survey, there were obtained from Prof. A. E. Nordenskiöld specimens marked cleveite from four localities near Moss, Norway, and to Prof. W. C. Brögger are due my thanks for specimens of Blomstrand's original bröggerite, and of the supposed thorium-free uraninite analyzed by Lorenzen[2] and quoted by Blomstrand[3] as a striking proof of the correctness of his view that all varieties of uraninite may be referred to the orthouranate type. These six samples contained, without exception, thoria and other earths, in no case less than 8 per cent, and the four from Prof. Nordenskiöld, with one exception, proved not to be cleveite. Notwithstanding certain variations in composition they were evidently one and the same mineral, just as were those from Branchville and Glastonbury; and the Norwegian and Connecticut varieties, though differing greatly in their relative proportions of UO_2 and UO_3 and in their resistance to the solvent action of acids, were manifestly specifically identical.

These analyses had been practically completed and a portion of the results very briefly communicated to the public from time to time,[4] when in consequence of a certain observation and its results an entirely new direction was given to the work and its scope wonderfully broadened. This was the discovery of a hitherto unsuspected element in uraninite, existing in a form of combination not before observed in the mineral world. As already published[5] all tests unite in showing

[1] Am. Jour. Sci., 1889, [3] vol. 38, p. 482.
[2] Geol. För. Förh.; vol. 6, p. 744.
[3] Journ. prakt. Chem., 1884, vol. 29, p. 223 ff.
[4] Am. Jour. Sci. 1888, [3], vol. 36, p. 295; Bull. U. S. Geol. Survey No. 60. 1887-1888. p. 131.
[5] Am. Jour. Sci., 1889 [3], vol. 38, p. 329, whereby a typographical error UO_4 is made to read NO_2.

that this element is nitrogen, which is given off in a gaseous form on heating the mineral with a non-oxidizing acid, or, as ascertained later, by fusing it with an alkaline carbonate.

It is very unfortunate that this discovery of an escape of gas when treated with an acid, or rather the recognition of its important bearing, for the observation was made at an early date, did not occur sooner; for then more satisfactory results could have been obtained with the in more than one respect most valuable material from Branchville, and nearly all the analyses would have been carried out with the most painstaking care, in order to secure the utmost possible accuracy in summation, the importance of which will appear in the sequel. Inasmuch as the analyses were made solely with a view to ascertain the percentages of rare earths and the relative proportions of UO_2 and UO_3, where a variation of half a per cent or even more from the true summation was of very little consequence, that extreme care in the preparation and use of reagents and in analytical manipulation which subsequently acquired knowledge showed to be so necessary was not exercised. Partly in consequence of this and partly because of the length of time required for these investigations caused by a want of abundant material, which necessitated oftentimes awaiting the result of one experiment or analysis before venturing upon another, it has been impossible to bring this investigation as far forward as was expected. So much time has elapsed since it was begun, and results of so much importance have been achieved, that it seems advisable to make them public now in detailed form, incomplete as they are in some respects and difficult of interpretation in certain directions.

Before proceeding to discuss the analyses themselves it is necessary to give in some detail the methods of analysis pursued, in order that the degree of credence to be accorded the results may be fairly weighed, and to present the evidence upon which the gas obtained from uraninite has been pronounced nitrogen.

PREPARATION OF SAMPLES FOR ANALYSIS.

As a prelude to the description of analytical processes employed, the manner of freeing the sample as far as possible from adhering gangue may be briefly described. The specimens consisted, except in the case of the amorphous Colorado, Bohemian, and Saxon varieties, of crystals and crystal fragments more or less coated and invaded by a feldspar or mica, or both, sometimes by columbite or a little quartz, and the surfaces opened up by fractures were often more or less coated with a reddish infiltration product which was little, if at all, soluble in the weak nitric acid employed for dissolving the uraninite on commencing an analysis. The sample was reduced to two or three grades of fineness by crushing and passing through several small sieves superposed one upon the other, care being taken to form as little fine dust as possible. When all had passed the coarsest sieve, the different fractions were

washed by decantation to free from dust, and then carefully panned in watch-glasses of suitable sizes. By this means all the mica and the greater part of the other lighter impurities were removed and a very fair degree of purification was reached. The columbite, if present, remained mostly with the uraninite, but caused little subsequent trouble. When no more gangue could be panned out without too great loss of material, the different portions were united, the specific gravity of the combined sample dried at 100° C. was taken, and it was then finely ground. The fine dust formed in the preliminary crushing was not used, unless for qualitative work, being generally too much contaminated with gangue. The panned material was always examined under the lens when dry, and aside from an occasional adhering reddish fragment appeared clean and free from foreign bodies.

METHODS OF ANALYSIS.

Ordinarily not less than two grammes was taken for the main analysis. Solution was effected in the least possible quantity of weak nitric acid at the temperature of the water bath so as to dissolve as little of the gangue as possible. When disengagement of gas bubbles had entirely ceased the uraninite was decomposed. Any black powder then remaining was treated as gangue, being columbite. The gaseous products of decomposition of the nitric acid are but faintly reddish. After filtering, the insoluble matter was ignited and weighed. A necessary refinement in cases where the amount of gangue is appreciable is to weigh it at 100°C. and then to ascertain how much, if any, water it contains. The filtrate was evaporated to dryness in platinum to obtain soluble silica, which after weighing was tested as to purity by hydrofluoric and sulphuric acids. From the filtrate lead was thrown down by hydrogen sulphide and weighed eventually as sulphate. Iron and manganese were then removed as sulphides while the earths and uranium were held in solution by ammonium carbonate and ammonia. This was effected in a flask of not over 250cm³ capacity, in which the precipitate was allowed to settle over night. A precaution to be observed is to add ammonia as well as ammonium carbonate, otherwise the earths thrown down with uranium on neutralization of the originally acid solution will be only partially redissolved. In order to ascertain this it is best to remove the hydrogen sulphide from the filtrate from lead sulphide before proceeding to the precipitation of iron. On adding ammonia and ammonium carbonate it can then be readily seen when the earths are dissolved, which is not at all easy if the hydrogen sulphide has not been first expelled. Calcium could rarely be found with the iron. The sulphide precipitate and the filter were roasted and weighed as a check, and then iron was separated from manganese if necessary, and the amount of the former determined as Fe_2O_3, which was generally checked by resolution, reduction by hydrogen, and titration by potassium permanganate.

If any doubt had existed as to the completeness of separation from the earths, the iron and manganese were a second time precipitated as sulphides in the presence of ammonia and ammonium carbonate.

The filtrate, or filtrates as the case might be, were gently heated till all ammonium carbonate was driven off, the precipitate was dissolved in nitric acid, and separation of earths and uranium from any traces of magnesia and alkalies present effected by freshly prepared ammonium sulphide, allowing to digest for an hour in a covered platinum dish on the water bath. As others have experienced, it was found that no separation from calcium can be effected by this method. While this element was always present in small quantity, it could very rarely be detected in the filtrate. Nevertheless the above method was preferred to that of Alibegoff[1], in which uranium is separated from alkaline earths, magnesium, and alkalies by mercuric oxide, because of the necessity of converting the nitrates into chlorides for the success of the latter operation, whereby an additional reagent is employed and the manipulations are increased, both of which it was desired to reduce to a minimum.

From the precipitate of earths and uranous oxide mixed with sulphur, the oxides were extracted by nitric acid, the solution was evaporated to dryness, water was added, and then when boiling, oxalic acid and two or three drops of ammonium oxalate. The precipitated oxalates were washed in due time with weak oxalic acid solution, ignited, and preserved in the crucible till later. The filtrate, which still always contains some rare earth metals and calcium, was evaporated to dryness, ignited to destroy oxalates, redissolved in nitric acid and evaporated with sulphuric acid in quantity slightly more than sufficient to convert into sulphates. After removal of all nitric acid the residue was dissolved in a little water and two and a half to three times the bulk of alcohol was added. In the course of twelve hours or more the precipitate, containing all the calcium not originally thrown down by oxalic acid besides some sulphates of the rare earths, was collected on a filter, washed with alcohol, dried, dissolved in weak nitric acid, and the rare earths were separated from calcium by ammonia and weighed with the main portion.

The alcoholic filtrate was evaporated to dryness, ignited, dissolved in nitric acid, and the precipitate produced by boiling with ammonia was ignited repeatedly in air and in hydrogen until a constant weight was reached by reduction. The UO_2 thus obtained was apparently never entirely free from rare earths, amounting usually to a quarter or a third of a per cent of the mineral. They were in two analyses recovered by treating the perfectly dried nitrates with ether, filtering, washing with ether, dissolving the insoluble nitrates of the earths and some uranium in water acidulated with a drop of nitric acid, and then adding oxalic acid to the hot aqueous solution after evaporating to dryness. The

[1] Ann. d. Chem., 1886, vol. 233, p. 133.

earths were weighed with the already tared main portion, and a proper deduction was made from the uranium oxide. It is best always to make a second precipitation by ether to insure extracting the last traces of earths from the uranium.

The earths as weighed contain the balance of the calcium and a small quantity of uranium. Solution was effected by prolonged digestion with sulphuric acid somewhat diluted, repeated after filtration if necessary. Thorium, cerium, lanthanum, and didymium were then separated from the yttrium earths by potassium sulphate in as nearly neutral a solution as could be obtained. Thorium and cerium were separated from lanthanum and didymium by long passage of chlorine gas through a solution of sodium hydrate holding the gelatinous hydrates of the earths in suspension. Finally thorium was separated from cerium by boiling with sodium hyposulphite. Small quantities of what might be zirconia were now and then found, but its identity could not be proved.[1] The turmeric paper test for this element has never proved of any value in my hands where small amounts of it were present. The earths of the yttrium group and the uranium were precipitated from the potassium sulphate solution by ammonia, redissolved in nitric acid, the solution was evaporated to dryness, and the earths were precipitated from aqueous solution by oxalic acid and weighed, after which they were examined for calcium, as was also the filtrate from them containing the uranium and that containing the potassium sulphate, in both of which calcium might be found. The combined calcium oxide was deducted from the original weight of the earths and added to the lime earlier separated by alcohol. The small amount of uranium recovered—usually 4 to 7 milligrammes as UO_2—was likewise deducted from the earths and added to the main portion.

In the last analysis of Glastonbury uraninite, which was made especially with a view to great accuracy in summation, and in analysis XVIII, a modification was introduced at one point which is perhaps worthy of retention in future work. Instead of evaporating the filtrate from iron sulphide to complete removal of ammonium carbonate, the gradually forming precipitate of carbonates was removed by filtration at a point where the earth carbonates are almost entirely thrown out and the uranium is still in solution. A little practice enables one to recognize this point readily. When the filtrate is treated as already described in the first method oxalic acid will generally fail to show any earths present with the uranium, but the precipitation by alcohol, and later by ether, must not be neglected. The carbonates are now dissolved in nitric acid, the solution is evaporated to dryness and the rare earths are separated by oxalic acid in perfect purity, except perhaps for a little lime, from the small amount of uranium they contain. The resulting filtrate will always contain a little of the earths, for it has been my experience that the precipitation by oxalic acid is never abso-

[1] Except in the Colorado uraninite, which contains practically no other earths than zirconia.

lute. It is best to unite it with the main portion of uranium and separate lime and some of the earths at the proper stage by alcohol, and from the weighed UO_2 the remainder of the earths by ether. So far as my limited experience with this modification goes it has proved satisfactory and decidedly preferable to the procedure first given, the chief point gained being that a purification of the earths from uranium is unnecessary and the trustworthiness of the weight found for the combined earths is heightened.

It may be said as regards the purity of the different earths or groups of earths after separation that, whereas the original ignited mixture was somewhat dark, without sharply characterizable color tint, the thoria was pure white and gave the theoretical molecular weight; the ceric oxide dissolved with a strong yellow color in concentrated sulphuric acid, which was bleached instantly by sulphurous acid, and with lead peroxide and nitric acid it gave likewise a deep yellow color; the lanthanum and didymium were cinnamon-brown in color, soluble in weak nitric acid, and the gelatinous precipitate by ammonia from acetic acid solution gave sometimes a blue color with powdered iodine, due to lanthanum; the yttrium earths were pale straw-colored and dissolved very readily in weak acids. Although only a single separation of the yttrium group by potassium sulphate was made, it was probably nearly perfect, for any remainder should have been obtained subsequently with the lanthanum and didymium, and the quantity of these was so small as to preclude much contamination by earths of the yttrium group.

Concerning the estimation of magnesia and alkalies and traces of phosphoric acid nothing need be said.

Water was estimated by heating the mineral in a current of air and collecting the water in a calcium-chloride tube. In only one case—the last Glastonbury analysis—was the mineral fused in a boat with sodium carbonate in order to retain the substance or substances which imparted to the water expelled by simple ignition an acid reaction. The weight of water found was hereby slightly reduced, and perhaps a similar result would have followed the taking of a like precaution in other cases. The acid property of the water was perhaps due to fluorine, since a trace was found in the Glastonbury mineral, but by no means enough to account for even the slight difference observed between the gains of the absorption tube by the two modes of ignition.

The correct estimation of UO_2 is of the utmost importance, and it was in consequence of remarkable variations in results first obtained that much material which would have been of inestimable value at a later period was used up in endeavors to secure concordance. An obvious source of error at first was the formation, in the sealed tubes in which decomposition of the mineral with rather strong sulphuric acid was effected, of bright green crystals of a thorium-uranous sulphate which

were almost insoluble in water, and hence necessitated such a length of time for titration as to seriously discredit the results. Dilution of the acid proved a remedy for this difficulty, and perfectly satisfactory solution[1] was obtained with one volume of concentrated sulphuric acid to six volumes of water. This proportion was employed in all subsequent work by this method, and decomposition of the uraninite was generally complete by leaving the tubes in an air bath over night at a temperature of 150–175° C. The end reaction with potassium permanganate was then always sharp and satisfactory, but the results were still discordant. The cause was eventually found to be in the manner in which the tubes were filled with carbon dioxide. This was done by introducing either solid sodium carbonate or a solution of the same and sealing as quickly as possible. It is, however, almost impossible to prevent access of air, often in considerable amount, through the drawn-out neck of the tube before the seal can be made. The following figures are the results of titration on one sample of Glastonbury uraninite. They are tolerably concordant compared with other series and yet are undoubtedly one and all too low. UO_2 found 55·00, 54·12, 56·98, 55·93, 56·15, 55·61. Every now and then a result would fall so far below all others of a series as to be positively startling.

When, however, the tubes were filled with carbonic acid from an external generator through a fine glass tube drawn out of the same kind of glass as that of which the decomposing tube consisted, and the fine tube was sealed into the other while the gas continued to pass, all air except the trace in the carbonic acid itself was excluded, and after decomposition the titration results showed a concordance and accuracy that could not be surpassed, as shown by the following series made on carefully purified U_3O_8, using freshly boiled distilled water:

UO_2 found 32·11, 31·90, 32·15, 32·12, 32·06, 32·17, 32·28.

Theory requires 32·07.

That it is immaterial whether the water is free from oxygen or has stood for some days exposed to the air is shown by the following series in which water several days old was used:

UO_2 found 32·11, 31·85, 32·37, 32·36, 32·13.

An excess over theory is to be expected, for it is difficult to prepare U_3O_8 with the theoretical percentage of UO_2.

In order to test the probable error of previous titrations the following

[1] Although the green crystals were no longer formed, there still appeared, as when stronger acid was used, a curious crystallization, taking the form of excessively fine needles woven into a felt-like mass which covered the surface of the liquid from end to end of the tube, and when put in motion by a movement of the solution resembled an undulating white rope. This was readily soluble in water and did not affect the titration at all, but it was observed on a few occasions, when the heating of the tubes was continued for several days, that it gradually disappeared and in its place an abundant crop of unusually large and clear green crystals was formed. Of the latter ·5209 gramme gave on analysis: UO_2 49·53, ThO_2 3·61, SO_3 32·32, H_2O 13·59; total, 99·05; whence is derived the molecular ratio UO_2 (ThO_2):SO_3:H_2O as 1:2·06:3.84, and the formula $(UTh)O_4(SO_3)_2$, $4H_2O$. Being formed from a much more dilute acid they may possibly differ from the crystals deposited from strong acid in the number of molecules of water. It is intended to make a more thorough examination of this salt at some future time.

determinations were made in which the tube was filled as carefully as possible with carbonic acid by using a solution of sodium carbonate:

UO_2 found 31·06, 31·07, 29·72, 29.33, 29·89, 30·69.

Theory requires 32·07.

Two out of the three experiments by Zimmerman,[1] in which UO_2 in U_3O_8 was estimated by permanganate after solution by hydrochloric acid in sealed tubes, using manganese sulphate to counteract the effect of the acid, gave 31·39 UO_2 instead of 32·07.

Finally a set of tests was made on a specimen of North Carolina uraninite in order to ascertain the degree of concordance to be reached on the mineral.

UO_2 found 38·14, 38·12, 38·12, 38·04, 38·07, 37·97, 37·87. Solution in the last two cases had been effected at 100° C., and was, perhaps, not quite perfect.

It is thus apparent that with due regard to the exclusion of all air from the tube, the method leaves nothing to be desired as regards accuracy. The acid employed was specially distilled and gave with brucine and diphenylamine no indication of nitric acid, the test being made as prescribed by Wagner[2], and it was absolutely without decolorizing power on permanganate. When wanted, a portion was diluted with about twelve volumes of water and boiled down to half the bulk, when it was rapidly cooled. In the mean time the mineral, in quantity from 0.3 to 0.5 gramme, having been introduced into the tube, about 2 cm.^{3} of distilled water was added and brought to boiling for a few moments in order to expel air from the powder. When somewhat cooled, from 15 to 30 cm.^{3} of the dilute sulphuric acid, according to the amount of mineral and the size of the tube, was added, and then the carbonic acid, which had been allowed to generate and escape from the apparatus for some time, was introduced and the seal was made as above described. No breakage of a tube in the oven ever occurred as a consequence of fusing the one tube into the other. The titrations were made in about half a litre of water, to which sulphuric acid had been added, as rapidly as possible, using a dilute solution of potassium permanganate, giving about 0·00036 gramme oxygen to the cubic centimetre that had been standardized by iron wire of known contents in iron and checked by pure oxalic acid, and taking account of the expansion or contraction of the titer liquid if its temperature varied more than a few degrees from that possessed by it at the time of standardization.

Zimmerman[3] decomposed U_3O_8 for the purpose of estimating UO_2 by concentrated sulphuric acid in a current of carbonic acid, but this method is not very applicable to uraninite, owing chiefly to its greater insolubility, particularly when rich in UO_2. Whereas, according to Zimmerman, quantities of U_3O_8 up to 1.2 grammes are decomposed thus

[1] Ann. d. Chem., 1886, vol. 232, p. 287, lines 5 and 6.
[2] Ann. d. Chem., 1886, vol. 232, p. 285.
[3] Zeit. f. Anal. Chem., 1881, p. 329 ff.

in an hour, uraninite may be only moderately attacked after many hours boiling. The whitish green insoluble salt which soon separates out undoubtedly exerts a retarding effect in protecting the rest of the uraninite powder from the action of the acid. A couple of tests were made by this method which accorded fairly well with the others, but owing to the great uncertainty of securing complete decomposition they were not multiplied.

In the early part of the present investigation, when want of concordance in the results of UO_3 titrations was the rule, decomposition by hydrofluoric acid was sometimes employed as a method leading to the estimation of UO_3 gravimetrically, and the results go to show that this may be developed into a method of considerable accuracy, useful at any rate as a check upon the volumetric determination.

All uraninites, without exception, are decomposed completely by hydrofluoric acid, even in the cold, if time enough is given, the uranous uranium being thrown down with the earth metals and lead as an insoluble fluoride. The refractory Glastonbury variety was thus decomposed in about ten days. In order to accelerate action, the acid and very fine powder were placed in a wide and perfectly flat platinum dish provided with a loose fitting cover, which was set in a dentist's vulcanizer containing a solution of sodium carbonate to absorb acid vapors. Dish and vulcanizer having been filled with carbonic acid gas, the lid was adjusted, and a lamp placed beneath, so that decomposition should take place under high temperature and pressure, and in absence of air. The main difficulty in the subsequent manipulation, and probably the only element involving possible serious error, is the difficulty of washing the precipitate on the filter, owing to its strong tendency to run through as soon as washing begins. Experience seemed to show that this is best obviated by using water containing ammonium chloride and hydrofluoric acid, but the experiments made were too few in number to show whether the method can be developed into an exact quantitative one. An attempt will perhaps be made to perfect it. The following are some of the results obtained:

A specimen of Glastonbury uraninite, giving on a basis of 57·43 per cent UO_2 by titration 26·48 per cent of UO_3, gave gravimetrically 26·89 and 28·58 per cent UO_3.

Another specimen from Glastonbury, giving by titration 59·31 per cent UO_2, gave gravimetrically 60·05 per cent.

Colorado uraninite, giving 58·51 UO_2 by titration, gave 58·24 per cent gravimetrically.

A few trials with U_3O_8 gave results in part less satisfactory, namely, 34·89, 31·26, and 28·47 per cent UO_2 instead of 32·07.

Assuming the practical insolubility of UF_4 in hydrofluoric acid, the method should give a tolerably exact separation of UO_2 from FeO and UO_3, and thus in connection with the oxygen used in titration indicate the state of oxidation of iron, as well as uranium, in substances con-

taining both where one does not predominate so enormously over the other as in uraninite. Even from Fe_2O_3 the separation should be exact, unless in the moment of breaking up of the molecule the ferric iron should exert an oxidizing effect on the uranous uranium before the latter is withdrawn from its influence by combination with fluorine. Hydrogen sulphide being without reducing effect on UO_3, the presence of sulphides would be immaterial so far as the separation of UO_2 from UO_3 and the oxides of iron is concerned, but of course the correct estimation of total oxygen by titration would be impossible if iron were present in its peroxidized state, or if even in its absence the hydrogen sulphide formed could not be expelled before titration.

It may be worth while before leaving the subject of estimation of uranium to add that, in accordance with Zimmerman's observations, I have met with no evidence of the existence of an oxide U_2O_5 as a result of strong heating in air, and the oxide U_3O_8, as he has so conclusively shown, is also by my own experience only to be obtained with its theoretical percentage of oxygen by igniting and cooling in oxygen.

DETECTION AND EXAMINATION OF NITROGEN.

At an early stage in the work it was noticed in a few instances where the sealed tubes in which UO_2 was to be estimated were left in an upright position for a short time, that an extremely slow disengagement of gas took place, which was especially noticeable if the tubes were gently tapped on the table occasionally, whereby the bubbles enmeshed by the powder were set free and rose through the liquid in the tube. This was supposed to be due to the presence of traces of carbonates in the mineral, and no particular attention was paid to it, although it seemed strange that they should not be entirely decomposed in a very few moments after contact with the acid. Later, when making the first estimation of UO_2 in Glastonbury uraninite above mentioned with hydrofluoric acid, solution in this case being made in the cold and with free access of air, it was observed that this slow escape of gas was continuous throughout the whole ten days required for decomposing the mineral. This seemed to exclude the possibility of its being carbonic acid, and it was determined to collect and examine it if possible. This was done in a manner to be hereafter described.

It may be here mentioned that U_3O_8 and UO_2 prepared from the residues obtained during this work, when examined under conditions precisely similar to those obtaining with uraninite, failed to give off the least trace of gas.

The gas was colorless, odorless, a nonsupporter of combustion, unchanged by mixture with air, neutral to moistened litmus papers, not absorbed by caustic alkalies, and insoluble in water, at least its coefficient of absorption was so small as to be inappreciable without elaborate experimentation.

In a Bunsen's absorption tube, containing gas from the original bröggerite, a potash ball caused no diminution in volume, neither did potassium pyrogallate, thus showing the absence of carbonic acid and of oxygen. Transferred from the absorption tube to a eudiometer the gas was then subjected to the tests prescribed by Bunsen.[1]

	Units.
Reduced initial volume	14·01
After exploding with oxyhydrogen	13·21
After a second similar treatment	13·20
After addition of hydrogen (32·79)	45·99
After explosion with oxyhydrogen	45·93
After addition of air in excess	181·82
After exploding	132·81
Contraction	49·01

two-thirds of which, or 32·67, is almost exactly the volume of the hydrogen introduced. Were it not for the relatively large contraction after the first explosion, 0·80 units, representing 5·71 per cent of the initial volume, the above tests would indicate almost incontestably that the gas could be nothing but nitrogen. Considering the small volume operated upon, and the great disadvantages under which the eudiometric experiments were made, the above is not a surprising error, and since in other experiments it did not recur, I have no hesitation in regarding it as without significance.

Gas liberated from bröggerite by hydrochloric acid had, after treatment in the absorption tube, in the eudiometer—

	Units.
A reduced initial volume of	27·73
After addition of hydrogen (25·77)	53·50
After exploding with oxyhydrogen	53·17
After addition of air	178·08
After exploding	138·20
Contraction	39.88

two-thirds of which, or 26·58, is sufficiently close to the volume of hydrogen added to show the purity of the gas.

Gas evolved from Branchville uraninite by sulphuric acid gave in the eudiometer

	Units.
An initial volume of	17·98
After exploding with oxyhydrogen	18·11
After addition of hydrogen (20·37)	38·48
After exploding with oxyhydrogen	37·36
After addition of air	106·32
After exploding	77·74
Contraction	28·58

two-thirds of which, or 19·05, is nearly that of the hydrogen introduced. The admission of a trace of air into the eudiometer with the gas or later with the hydrogen would account for the slight contraction

[1] Gasometrische Methoden, 2d ed., pp. 73, 74.

after the second explosion and for the deficiency in the observed over the calculated final contraction. But such an assumption is hardly necessary, for the final readings on the eudiometer tube were very uncertain.

The evidence as to the nature of the gas while fairly conclusive was thus far purely negative. Proof of a more positive character was needed, and this was sought in various ways.

Long continued passage of the electric spark between the platinum wires of the eudiometer, in which was a mixture of the gas with pure oxygen, produced a marked contraction, and a few drops of water purposely introduced above the mercury before turning on the current gave, when taken out and tested with diphenylamine, and brucine, intense blue and red colors, respectively. Blue litmus paper was turned red by it. When the terminals of a Ruhmkorff coil were connected with a simple modification of Siemens's induction tube, devised for the employment of small quantities of gas, containing a mixture of the gas with 3 volumes of electrolytic hydrogen, a slow but constant contraction resulted, provided that the product of combination as fast as formed could be removed by water or an acid. A strip of moistened red litmus paper suspended in the apparatus turned deep blue, and water used as an absorbent gave a strong alkaline reaction with litmus, besides affording with Nessler's reagent the characteristic ammonia reaction in a marked manner. With dilute hydrochloric acid as an absorbent there was obtained 0·0190 gramme of ammonium-platinic chloride, which when heated with sodium hydrate gave off a strong ammoniacal odor, and a strip of red litmus paper held above the mixture was instantly turned deep blue. The nitrogen calculated from the above weight of $(NH_4)_2PtCl_6$ is 0·00121 gramme, or nearly 1 cubic centimetre at 0°C. and 760 millimetres. The roughly measured contraction of the mixed hydrogen and nitrogen gases was in accordance with this determination. It should be hardly necessary to say that all these chemical tests were duplicated simultaneously in blank.

In a Geissler tube under a pressure of 10 millimetres and less the gas afforded the fluted spectrum of pure nitrogen as brilliantly and as completely as was done by a purchased nitrogen tube. In order that no possibility of error might exist, the tube was then reopened and repeatedly filled with hydrogen and evacuated until only the hydrogen lines were visible. When now filled with the gas and again evacuated the nitrogen spectrum appeared as brilliantly as before with the three bright hydrogen lines added.

The success of these electrical experiments with Geissler and Siemens tubes is very largely due to Dr. William Hallock of the physical laboratory of the Geological Survey, for whose ever ready assistance and ingenuity in meeting difficulties I can not too strongly express my appreciation.

ESTIMATION OF NITROGEN.

The original apparatus for collecting the gas is depicted in the accompanying figure.

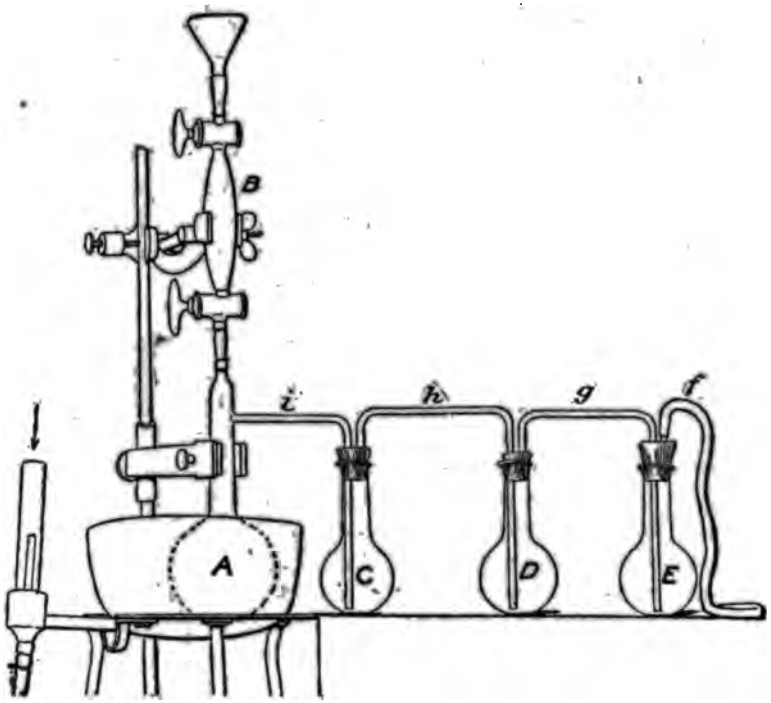


FIG. 1.—Apparatus for collecting nitrogen.

The decomposing vessel A is simply a fractional distillation flask of not more than 100 cm³ bulb capacity, drawn out at the top to allow of connection by means of rubber tubing with the receiver B, which should approach the cylindrical in form, be provided with two closely fitting, wide bore stopcocks, and have a capacity of 25 to 30 cm³. The very fine powder having been introduced into A and boiled with a few cubic centimetres of water to expel air, connection is made with B by tubing firmly wired, the receiver is suitably supported by a clamp so that A shall have the position given in the as yet empty water bath, and the flasks C, D, E are placed in position, fitted with corks and tubes as represented, but not yet closed by the corks. A rubber tube being now attached to B at the top, a thoroughly boiled sulphuric acid having the strength of that used for UO_2 estimations ($1H_2SO_4$: $6H_2O$ by volume) is poured into C, and continuously sucked into A and then into B until the latter is full above the upper stopcock, when this is instantly closed. C is then filled up with the same acid, and the water bath with water to relieve somewhat the strain on the rubber connection between A and B. E and D are now filled with freshly boiled dis-

tilled water, and the cork of E is pressed down. Then by blowing in at *f* the air in *g* is expelled and D can be corked without retaining the least bubble of air. By continuing the blowing *h* may be freed from air and C tightly corked. A may now be clamped in position for greater security, and a tin cover provided with a slit for the neck of A placed over the water bath. This is primarily to prevent the action of steam on the rubber connection between A and B, by which after several days it is softened and injured, and secondarily to economize heat. On top of B is attached a small short-stemmed funnel, which is kept filled with distilled water, in order to insure a water seal about the stopcock and certain exclusion of all air. Heat is now applied to the water bath, which is provided with a constant level arrangement and flow of water, so that it may be heated night and day without interruption. Soon an evolution of gas begins, the bubbles rise through A and the lower stopcock into B, and continue until the mineral is entirely decomposed. The fine powder which is carried up into B by the bubbles may be in great measure returned to A by tapping B, and if not, it is decomposed by the moderately warm acid in B, especially in case a readily soluble uraninite is being treated. The tube *i* should be very nearly horizontal, in order to prevent any of the powder reaching C as it falls from B. What little may collect along *i* itself will decompose in time and the gas from it reach B. The outlet tube of E not being closed, free movement and escape is afforded for water in E as acid in B is displaced by gas. C, D, and E likewise act as checks to the diffusion of air into B. One, or at most two, flasks would suffice where readily soluble uraninites are treated, and the duration of the experiment is at most twelve hours, but for refractory varieties a third is indispensable. The greatest difference exists between North American and Norwegian uraninites as to their solubility in sulphuric, hydrochloric, hydrofluoric, and even nitric, acids. Whereas the Colorado and both Connecticut uraninites are not entirely decomposed by nine days' continuous treatment at 100°C. with dilute sulphuric acid in the above-described apparatus, and even the much-altered North Carolina mineral requires five days for solution, all the Norwegian specimens examined are completely attacked in much less than twelve hours, and one (from Arendal) in three. Hydrochloric acid was used in one instance in place of sulphuric in the apparatus and with about the same effect.

When no gas is any longer given off the mineral is decomposed, as may be seen by removing the water from the bath and examining the residue in the bottom of the flask. It is either pure white sulphate of lead, or dark colored if columbite was mixed with the uraninite. Owing to the large volume of acid used there is no separation of insoluble uranium or thorium salts as in the UO_2 estimations.

When the operation is ended B is disconnected from A after closing the lower stopcock, and the gas can then be readily transferred to a

graduated and rather narrow measuring tube, or it can be measured in the receiver itself, if this is graduated, by opening the lower stopcock under water and allowing the latter gradually to displace the acid in order that the vapor tension of pure water may prevail. All necessary thermometric and barometric readings having been made, the volume in cubic centimetres is reduced to 0°C. and 760 millimetres and multiplied by the weight of 1 cubic centimetre (·001256 gramme) of nitrogen, in order to obtain the weight whence the percentage is obtainable.

The error due to absorption of a portion of the gas by the acid liquid or by the water with which it is displaced in measuring is a vanishing quantity, because of the high temperature of the acid at the time of disconnecting and the low coefficient of absorption of both liquids for the gas. If transferred from the receiver to a measuring cylinder, the gas comes into contact with so much water that the element of absorption might have slight effect were time enough allowed; but the water levels within and without the measuring vessel having been brought into approximate accord, the temperature of the gas is reduced in a very few moments to that of the water by allowing a running stream of the latter to impinge on the top of the vessel and flow down on all sides, a thermometer being fastened thereto by a rubber band.

If necessary to use the solution for the titration of UO_2, disconnection of the apparatus and transfer of the gas can be so carried out that the result of titration is very nearly as exact as by the method already described.

The above described apparatus is well enough adapted for the estimation of nitrogen in readily decomposable uraninites, and admits of constant observation of its rate of evolution; but if the heating is continued beyond a few days, the glass of that portion of the decomposing flask under water becomes devitrified and more or less cracked. This does not necessarily prevent several days' further heating, but the danger of breakage is considerable. Moreover, but one experiment can be conducted at a time unless several sets of apparatus are available. Therefore recourse was had, in many cases, to decomposition in sealed tubes, exactly as described for UO_2 determinations, larger quantities up to 1 gramme of mineral being used, however, and the heating prolonged, if necessary, for two or three days to secure complete decomposition. After opening the tubes under water the gas was at once transferred by displacement of water to a test tube not too large to be closed by the thumb, a piece of potassium hydrate was rapidly inserted, the thumb placed over the mouth of the tube, and the latter agitated under water to dissolve the alkali and secure absorption of the carbonic acid. This was effected in a few moments, when pure water was allowed to displace the potash solution, and the gas was then transferred to the graduated tube and measured as before.

While the two methods of obtaining the nitrogen by decomposing with an acid gave pretty satisfactory results, it was desirable to estimate it by an entirely different process if possible. Fusion with alkaline hydrates produced no perceptible evolution of ammonia, and a quantitative combustion of bröggerite mixed with sugar by the soda-lime method and absorption of any ammonia by hydrochloric acid furnished an amount of $(NH_4)_2PtCl_6$ representing but 0·03 per cent. of nitrogen. Fusion with alkaline carbonates, however, liberated nitrogen gas and furnished a means of estimation that compared well with the acid method. The process was conducted as follows:

The substance mixed with sodium-potassium carbonate in a porcelain boat inclosed in a cylinder of platinum foil open at both ends was introduced into the rear end of a combustion tube already containing a considerable layer of copper oxide in the center, followed by eight inches of copper gauze plugs toward the front end. To the rear was attached a tube filled with manganese carbonate, and to the front a nitrometer containing potassium hydrate solution.

Repeated heating and cooling of the copper oxide and copper in a continuous current of carbonic acid having reduced the gas unabsorbable by the alkali solution to the smallest possible limit, heat was applied under the boat. The evolution of gas began long before incipient redness, and had to be soon checked by regulation of the temperature. Finally the heat was raised to fusion, and maintained there till the absorption of gas bubbles by the alkali was as complete as before beginning the experiment. The gas was then measured and reduced to 0°C. and 760 mm, with due regard to the vapor tension of the alkali solution, Kreussler's[1] table being used in this connection.

Of course the small quantity of nitrogen from which it is impossible to free the carbonic acid, even in a blank experiment, and which can not be allowed for with accuracy because it may vary slightly in each experiment, produced an uncertainty in the readings on the nitrometer, but one of very slight importance, since an admixture of even half a cubic centimetre of such nitrogen could affect the result by about 0·06 per cent. at the most when one gramme of mineral had been used. The platinum cylinder is a very necessary shield to prevent spattering of the contents of the boat onto the glass tube.

By this fusion in carbonic acid the lead contained in uraninite is apparently entirely reduced to the metallic state and collects in globules. This reduction is probably caused by the UO_2 of the mineral, notwithstanding the fact that litharge is not reduced when thoroughly mixed with U_3O_8 or UO_2 and fused with sodium-potassium carbonate under the conditions of the above experiment and for the same length of time. In the one case two molecules already existing must be torn asunder in order to admit of a rearrangement of their constituent atoms, while in the other these constituents are assumed to exist

[1]Zeit. f. Anal. Chem., 1885, vol. 24, p. 445.

already united in a single molecule, and in the moment of its breaking up are most favorably situated for rearrangement.

Nitrogen obtained in this way from Glastonbury uraninite was submitted in the eudiometer to the same ordeal as that obtained by acid, with the following results:

	Units.
Reduced initial volume	84·69
After exploding with oxyhydrogen	84·95
After addition of hydrogen (29·02)	113·97
After addition of oxygen (25·12)	139·09
After exploding	94·40
Contraction	44·69

two-thirds of which, or 29·79, is nearly the volume of hydrogen added. The gas then is the same as that disengaged by acids.

ANALYSES OF URANINITE.

The analyses which follow were with two exceptions, V and XVIII, made before recognition of the nature or importance as regards quantity of the gas given off by acid, and as before said their object was chiefly to ascertain the relative percentages of UO_2, UO_3, and rare earths with a reasonable degree of accuracy.

The specific gravities of the Connecticut mineral were so much higher than any published that considerable care was exercised in their verification and in all subsequent determinations. The figures given represent the density of the mineral dried at 100° C., for the small amounts of hygroscopic moisture, varying as they did with different specimens, would exert a marked effect on the result if included.

A knowledge of the condition of the iron, which all analyses show accompanies uraninite in small quantity, is of prime importance for the correct volumetric estimation of UO_2. Comstock and Blomstrand have both assumed that it exists in the ferrous condition and from the oxygen transferred in titration have deducted a corresponding amount before calculating UO_2. While not in a position to deny the correctness of this assumption for a portion of the iron at least, I have, with one or two exceptions which will be noted in due order, preferred to consider all iron dissolved by dilute nitric acid as ferric oxide, and for the following reason: The matter insoluble in dilute nitric acid may consist of columbite, feldspar, quartz, mica, a very sparingly soluble phosphate, and the reddish infiltration matter filling the minute seams in the mineral, substances which it is practically impossible to remove entirely from any sample containing them. When the uraninite is dissolved this insoluble matter is decidedly red (unless columbite predominates largely) from ferric oxide, of which it is probable the infiltration matter is largely composed. In all such cases a large percentage of the insoluble matter is ferric oxide, and only in one case could any ferrous oxide be found in it aside from that belonging to columbite. It was further noticed that more iron was found in solution and correspondingly less

in the insoluble when the heating had been prolonged beyond the usual time or when a stronger acid was employed. It seemed therefore certain that a portion of the iron in solution had been derived from ferric oxide of the gangue, and possibly all of it. It was impossible to tell how much, if any, might have existed in the ferrous condition, and therefore it seemed better to count the whole as ferric oxide. In any event the amount found is always so small as to affect the percentage of UO_2 but slightly, and never enough to cause trouble in comparing different analyses. That none of the iron belongs to uraninite itself appears from an experiment made upon Glastonbury material (No. V). When boiled for many hours with dilute hydrochloric acid till 25 per cent of the mineral had dissolved, not a trace of iron was left in the undissolved portion.

Proof is likewise lacking of the state of oxidation of cerium, but CeO_2 seems its more natural condition in the presence of other binoxides in overwhelming proportion. As with iron, however, its small amount renders this for purposes of calculation a matter of small importance.

It must be borne in mind that the combined earths are probably too low in all cases except Nos. V and XVIII, in which two precipitations of nitrates by ether were made to separate the last traces of earths from uranium. It is assumed that separation is then perfect, for by no known means could a further trace be extracted. That an appreciable amount of earths escaped separation in other analyses and went to increase the apparent percentage of UO_3 was at one time shown in working up some of the residues, amounting to ten or twelve grammes, for pure U_3O_8, when a considerable weight of earths was obtained, amounting to at least one-third of 1 per cent of the residues.

TABLE I.—*Uraninite from Glastonbury, Connecticut.*

	I.			II.	III.	IV.	V.		
	a.	b.	Mean.				a.	b.	Mean.
UO_3			22·06	23·35	23·23	‖26·48	23·13	22·94	23·03
UO_2	59·09	59·17	59·13	58·01	‡59·21	¶57·43			**59·93
ThO_2	9·09			9·78		9·79	10·01		
CeO_2						·25	·29		
ZrO_2†		9·59	9·57		10.31		·15	11·13	11·19
$(LaDi)_2O_3$	·55			·46		·13	·15		
$(YEr)_2O_3$						·20	·48		
PbO	3·14		3·14	3·24	3·07	3·26	3·08	3·08	3·08
CaO	·08		·08		undet.	·08	·17	·04	·11
MgO					undet.				
Alk					undet.	trace			
H_2O	·97		·97	undet.	undet.	·61	·43	·42	·43
N	undet.	undet.	undet.	undet.	undet.	undet.			††2·41
Fe_2O_3	*1·21		1·21	·33	§·67	·40	·28	·29	·29
MnO						trace			
SiO_2	1·06		1·06		·25	·16	·15	·18	·16
P_2O_5							·02		·02
Fl							·04		·04
Insol.	·85		·85	††1·74	·42	·79	·85	·92	·89
Cb_2O_5	·06		·06						
Total			99·05	96·91	96·25	99·49			101·49
All U as UO_2			79·96	80·06	80·29	82·43	81·75	81·59	81·67
Sp. gr			9·139	9·051		9·587			9·622
Temp. °C			17½	21		21			19·4

* Estimated by weight; probably contaminated by earths or by alumina. Another fragment gave ·43 Fe_2O_3.

† Containing ·55 SiO_2, ·86 Fe_2O_3, ·33 Al_2O_3 etc.

‡ Mean of 59·07, 59·15, and 59·71. Separation by HFl gave 60·05.

§ Too high, since it was estimated by weight and found to contain some rare earths.

‖ Gravimetrically after separation by HFl there was found 28·58 and 26·89.

¶ Mean of 57·46 and 57·39. Probably too low, and UO_2 consequently too high, since they were among the earlier determinations made and no material was left for verification after the method was perfected.

** Mean of 59·88, 60·07, and 59·83.

†† Mean of 2·39 and 2·46 by decomposition with H_2SO_4 in sealed tubes, and 2·33 and 2·46 by fusion with $NaKCO_3$ in a current of CO_2. The first determinations were made in the apparatus depicted on page 56, and gave 2·14 and 2·21 per cent, but decomposition was incomplete and the percentage was calculated on the assumption that the undissolved residue had the same composition as the portion dissolved, a view hardly tenable in the light of subsequent experiments (p. 74). They are, therefore, not used in deriving the mean given in the analysis.

I. From a large crystal nearly an inch across which was collected by Prof. F. W. Clarke, the analysis of which led to all subsequent work. It was much contaminated with reddish feldspar, quartz, yellow muscovite, and, as examination of the insoluble showed, with columbite, besides a reddish infiltration product lining cracks and becoming apparent on broken surfaces. Most of these were removed, but enough remained to render the analysis in some respects unsatisfactory. The amount of soluble silica indicated thorite as a possible source of the thoria, which the other analyses show can not be the case. The presence of such an amount of columbic acid in a readily soluble form, for it was obtained by boiling the nitric acid solution of the mineral after filtration from the insoluble matter, points to some columbate other than columbite. Microscopical examination of a thin section of the crystal showed a few cracks filled with a reddish brown and yellow material, part of which was a readily decomposable silicate of some kind, as evidenced by the fuchsine test after treatment with hydrochloric acid and washing with water, but the total visible impurity was very little. A portion of the water undoubtedly belonged to the foreign matter.

II. Obtained from Prof. W. N. Rice, of Middletown, Connecticut.

III. Collected by myself as small crystals and fragments. Only a very small amount was available.

IV. Obtained from Mr. E. F. Sheldon, of Middletown, Connecticut.

V. From the same source as No. IV, but at a later date. A very large irregular crystal of this lot was crushed and purified as far as possible, and with this material a very careful analysis, duplicated in part, was made for the purpose of obtaining an accurate summation. This analysis post-dates all others published in this paper except No. XVIII. In addition several estimations of nitrogen were made by the different ways mentioned already, and numerous experiments which it was hoped might throw light upon the ultimate composition of the mineral.

All the above material came from Hales's quarry, in the town of Glastonbury, a few miles northeast of Middletown, Conn.

TABLE II.—*Uraninite from Branchville, Connecticut.*

	VI.	VII.	VIII.	Comstock's analysis.
UO_3	13·27	21·54	14·00	46·06
UO_2	72·25	*64·72	†70·99	54·51
ThO_2	7·20	6·23	6 83	.....
ZrO_2?		·23		
PbO	4·25	4·24	4·25	4·27
MnO	·10	·07	‖	.....
CaO	·18	·22	·30	.....
MgO	.....	.....	·15	.....
Alk.	.....	.....		.....
H_2O	·68	·67	‡ .68	·33
N	undet.	undet.	§2·63	.....
Fe_2O_3	·11	·26	·27	FeO ·49
SiO_2	·93	·13	·20	.....
Insol	·04	·14	‖1·49	.....
Total	99·21	99·37	101·49	100·23
All U as UO_2	84·78	85·06	84·21	.....
Sp. gr	9·733	9·509	9·248	.....
Temp. °C.	27·7	·20	15·7	.....

*No material was left for a verification of this figure after perfection of the method of UO_2 estimation, but the low density compared with that of the others when corrected for insoluble matter of 2·7 sp. gr., and the fact that a UO_2 determination by Zimmerman's method (p. 51) in which, however, decomposition was not quite complete, gave 63·23 per cent, point to its correctness.

†Mean of 71.11 and 70.87.

‡Assumed as in VI.

§Only enough material for a single estimation was left, and being one of the earliest made it was carried out in the apparatus depicted on p. 56, wherein only 89·7 per cent of the powder had dissolved after about 210 hours, when the experiment was discontinued, because of danger of breakage to the flask. The figure here given is calculated on the basis of like composition for the dissolved and undissolved portions—an improbable assumption in the light of later experiments (p. 74)—and is probably too low.

‖The gangue was mainly reddish feldspar, and contained ·31 (or 22 per cent) Fe_2O_3 besides, but only an indeterminable trace of FeO as ascertained on a separate portion. The increase in the percentages of CaO, alkalies, and SiO_2, with progressive increase of insoluble matter, indicates clearly a partial solution of the feldspar.

VI, VII, VIII. This material was all received from Profs. Brush and Dana, of New Haven, and was the residue of the material from which Comstock had taken his for analysis. No. VI was by far the purest of any material obtained from any locality, the crystals and fragments being brilliant and well defined and almost absolutely free from impurity. It is earnestly to be hoped that more of this excellent material may be found at Branchville for closer investigation, since it represents the extreme of perfection as regards crystallization and freedom from attached and infiltrated foreign matter, besides possessing the greatest density and the highest percentage in UO_2 and nitrogen of any known variety.

TABLE III.—*Uraninite from Colorado and North Carolina.*

	IX. Colorado.			X. North Carolina.	XI. North Carolina.
	a.	b.	Mean.		
UO_3	25·26	.....	25·26	50·83	44·11
UO_2	58·47	58·56	58·51	39·31	46·56
TiO_2	trace.	trace.	trace.	.....	.....
ZrO_2	7·32	7·85	7·59	.....	.....
ThO_2	.....	.....	.....	2·78	
CeO_2	·22	·22	*·22	·26	3·04
$(LaDi)_2O_3$	.....	.....	.....	·50	
$(YEr)_2O_3$	.....	.....	.....	·20	
PbO	·69	·71	·70	4·20	4·53
ZnO	·43	·44	·44	.....	.....
FeO	·32	.....	†·32	trace.	.....
MnO	·16	.....	·16	.....	.....
CaO	·84	·85	·84	·85	·23
MgO	trace?	.....	trace?	·30	·25
Alk	trace?	.....	trace?		
H_2O	1·96	.....	1·96	1·21	undet.
N	·15	.....	‡·15	§·37	undet.
SiO_2	2·76	2·82	2·79	·08	·13
P_2O_5	·22	.....	·22	?	.....
As_2O_5	·43	.....	·43	.....	.....
$CuFeS_2$	·12	.....	·12	.....	.....
FeS_2	·24	.....	·24	.....	.....
Insol.	.....	.....	.....	·10	·06
Total	.....	.....	99·95	100·99	98·91
All U as UO_2	.....	.....	82·36	87·31	88·21
Sp. gr.	.....	.....	8·068	8·086	9·492
Temp., °C	.....	.....	20	15·8	20

*Lanthanum not tested for.
† Calculated from total iron after deducting that required by pyrite and chalcopyrite.
‡ By fusion with $NaKCO_3$. H_2SO_4 failed to decompose entirely in nine days at 100°C.
§ Mean of ·38 by fusion with $NaKCO_3$ and ·35 by H_2SO_4.

IX. From a specimen in the National Museum from near Black Hawk, Colorado, where the mineral was originally identified by Mr. Richard Pearce about 1872. A very few tons represented the total product of the mine in uraninite, which was shipped to Great Britain for treatment.

This variety, differing in some respects so markedly in composition from all other known uraninites, is also distinguished from the other North American occurrences by its utter want of crystalline form. The specimen examined was largely contaminated with pyrite and chalcopyrite; in places it consisted of these alone, in others of pretty pure uraninite. But the purest of the latter was seamed with minute cracks filled with sulphides. A section as thin as possible showed under the microscope absolutely no other impurity. The material used for analy-

sis was obtained after sifting to grades of fineness by first panning and then exposing the partly cleaned grains in a specially devised apparatus to an upward current of water, through which the heavy uraninite fell while the sulphides were held up. It was then further purified by most laborious hand picking under the lens. Even so it was impossible to free it altogether from sulphides, as the analysis shows, and this is especially unfortunate because of the uncertainty which is thereby thrown upon the UO_2 estimations. These, as above given, *include* the effect of any hydrogen sulphide and ferrous iron formed by the solvent action of sulphuric acid and of ferrous oxide possibly already existing. That they are not far from correct, however, is evidenced by a gravimetric estimation of UO_2 after separation by hydrofluoric acid, where sulphides and ferrous iron would be without effect, which gave 58·24 per cent UO_2. Another element of uncertainty in the volumetric determination is caused by want of knowledge of the condition in which arsenic is present. It has been assumed as As_2O_5, mainly for the reason that when even dilute nitric acid was used for dissolving, hydrogen sulphide precipitated the arsenic only after a considerable time. The condition of the zinc is likewise unknown. Its most natural form would be as sulphide, but as the sulphur was insufficient for the zinc alone, the negative element has all been credited to pyrite and chalcopyrite.

The analysis presented considerable difficulty. It was found that on solution in nitric acid a dirty white residue was left which contained silica, zirconia, and phosphoric acid, and that on boiling a further precipitate of zirconia containing phosphoric acid came out. None of the silica was present as quartz, for the residue in nitric acid was entirely free from grit; nor can it have been combined with zirconia as zircon for the same reason and because the latter is insoluble. But for the phosphoric acid it is probable that the residue would have held no zirconia, since a very little of the former seems able to carry down much of the latter, even in a very acid solution. The silica given in the analysis represents both that in the residue and that subsequently obtained by evaporation after boiling and filtering. The rest of the zirconia and the other earths were separated from uranium by potassium sulphate.

X, XI. From the Flat Rock mine, Mitchell County, North Carolina, through Mr. W. E. Hidden. Entirely unaltered uraninite seems never to have been found in North Carolina, and no analysis of it appears to have been made, though its alteration products have received attention. The crystal form of the original mineral is often preserved in the pseudomorphs, and it is decidedly more cubical than that of the Connecticut crystals, which are usually octahedral in habit. Even the least-altered material, though it may present a perfectly fresh aspect, is seamed in all directions by microscopic cracks filled with yellow alteration products. Such was the character of the piece used for analysis X, which was undertaken for the purpose of ascertaining whether or

not the North Carolina mineral contained rare earths. In order to observe the effect of a weak solvent another lump was immersed for several days in very dilute cold hydrochloric acid, whereby it gradually fell into a fine powder, which was washed, dried, and analyzed with the results given under XI.

TABLE IVa.—*Uraninite from Norway.*

	XII.		XIII.		XIV.		XV.		XVI.		XVII.	XVIII.
	Anneröd.		Elvestad.		Elvestad.		Skraatorp.		Huggenäskilen.		Arendal.††	Arendal.
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*		
UO_3	30·56	30·70	25·34	{25·49 25·26	{22·02	22·06	31·93	32·08	35·52	35·57	41·71	26·80
UO_2	46·20	46·07	50·76	{50·62 50·84	{43·05	43·01	43·95	43·81	43·36	43·39	24·18	44·18
ZrO_2	·06	.....	·08	.....	}	.....	.....	.....	.....	.....	.....	.....
ThO_2	6·00	.....	8·48	.....	}	.....	8·98	.....	6·59	}	}	4·15
CeO_2	·18	.....	·21	.....	} 8·43	.....	·17	.....	·20	} 8·13	} 3·66	none.
$(DiLa)_2O_3$	·27	.....	·26	.....	}	.....	¶·36	.....	·23	}	}	::·67
$(YEr)_2O_3$	1·11	.....	‡1·10	.....	}	.....	·97	.....	1·03	}	9·76	9·05
PbO	9·04	.....	10·06	.....	8·58	8·58	9·50	9·42	9·46	{9·45 9.41	10·54	10·95
CaO	·37	.....	·77	.....	·37	.....	·36	.....	·41	·41	1·06	·61
MgO	{ tr.	.....	tr.	.....	·13	.....	tr.	.....	·13	.....	{ ·10	·04
Alk	{	.....		.....		.....		.....		.....	{ ·23	·15
H_2O	·74	.....	·73	.....	·74	.....	·77	.....	·79	.....	1·23	undet.
N	1·18	†1·15	1·28	§1·20	1·08	.....	1·03	.....	1·08	.....	undet.	1·24
Fe_2O_3	.25	.....	·21	.....	·30	·31	·09	.....	·32	·31	·03	·24
MnO	.....	.....	·06	.....	.....	.....	.....	.....	.....	.....	.....	.....
SiO_2	·22	.....	·38	·39	·28	·30	·53	.....	·45	{·51 ·50	·90	·50
P_2O_5	·02	.....	·04	.....	tr.	.....	(?)	.....	tr.	.....	.....	tr.
Insol	*4·42	.....	·44	·46	‖15·50	15·41	**1·54	.....	·41	·43	1·10	1·19
All U as UO_2	75·06	.....	74·69	.....	63·84	.....	74·10	.....	76·90	76·98	63·57	69·49

* The gangue was mainly columbite and contained a total of ·61 FeO by trial on a separate portion. The columbite could be pretty well separated from the other and lighter gangue matter after solution of the uraninite in nitric acid, and it was found that of the total FeO ·30 belonged to the columbite and ·31 to the other gangue constituent. This latter was dissolved by the acid in UO_2 determinations, while the columbite was not; hence a correction has been made for ·31 FeO representing ·58 UO_2.

† The first result by fusion with $NaKCO_3$, the second by solution in HCl. Another result of 1·28 by H_2SO_4 was the first quantitative determination of nitrogen made and was probably too high through leakage of air into the receiver.

‡ Molecular weight, 277.

§ By fusion with $NaKCO_3$. The first result was obtained by H_2SO_4.

‖ Almost entirely columbite.

¶ Perhaps not fully freed from ThO_2.

** Mainly a phosphate.

††A brief but brisk effervescence was produced by acids. The deficiency in the analysis, 5·50 per cent., was supposed to be satisfactorily accounted for as CO_2; a portion of it, however, is probably to be credited to nitrogen.

:: The ignited oxides differed in appearance from the mixtures of La_2O_3 and Di_2O_3 obtained in all other analyses, being nearly colorless.

TABLE IV*b*.—*Means of analyses in Table IVa.*

	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
	Anneröd.	Elvestad.	Elvestad.	Skraatorp.	Huggenäskilen.	Arendal.	Arendal.
UO_3	30·03	25·36	22·04	32·00	35·54	41·71	26·80
UO_2	46·13	50·74	43·03	43·88	43·38	24·18	44·18
ZrO_2?	·06	·08					
ThO_2	6·00	8·48		8·98	6·63	3·66	4·15
CeO_2	·18	·21	8·43	·17	·20		none.
$(DiLa)_2O_3$	·27	·26		·36	·23		.67
$(YEr)_2O_3$	1·11	1·10		·97	1·03	9·76	9·05
PbO	9·04	10·06	8·58	9·46	9·44	10·54	10·95
CaO	·37	·77	·37	·36	·41	1·06	·61
MgO	tr.	tr.	·13	tr	·13	·10	·04
Alk						·23	·15
H_2O	·74	·73	·74	·77	·79	1·23	undet.
N	1·17	1·28	1·08	1·03	1·08	undet.	1·24
Fe_2O_3	·25	·21	·30	·09	·32	·03	·24
MnO		·06					
SiO_2	·22	·38	·29	·53	·49	·90	·50
P_2O_5	·02	·04	tr.	(?)	tr.		tr.
Insol	4·42	·45	15·45	1·54	·42	1·10	1·19
Total	100·61	100·21	100·44	100·14	100·09	94·50	99·77
Sp. gr.	8·893	9·145	8·320	8·966	8·930	7·500	
Temp., °C.	21·6	17	29·7	20	28·2	26·8	

XII. The original bröggerite, from Gustavsgruben, Anneröd, near Moss, received from Prof. W. C. Brögger, who writes "es ist das originale Vorkommen des Bröggerit Blomstrands."

XIII. Likewise from Prof. Brögger, labeled Uraninit, Elvestad b. Moss. In addition Prof. Brögger writes, "so viel ich weiss, von derselben Stelle wie das Originalmaterial Lorenzens."

XIV–XVIII. From Prof. A. E. Nordenskiöld, through Prof. F. W. Clarke, of the U. S. Geological Survey. These specimens all bore, with one exception erroneously as the analyses show, the name cleveite, on labels of the Royal Museum of Stockholm; XIV was from Elvestad, XV from Skraatorp, XVI from Huggenäskilen, all being localities near Moss, and XVII and XVIII were from Arendal. The Arendal material was not in separate crystals and fragments like the others, but was inclosed in the original matrix of feldspathic rock. Of this there were three or four small pieces, from one of which some very inferior-looking material was extracted. It had every appearance of being much altered, which the evolution of carbonic acid by acids and the abnormally low percentage of UO_2 seemed so fully to demonstrate that no particular pains were taken beyond separating the earths from uranium and dividing them roughly into two groups. The material was in any case insufficient for a carbonic acid estimation. Later it became of interest

to learn if this apparently greatly altered material contained nitrogen, and to this end further material was extracted from another of the pieces of rock. Its analysis unexpectedly gave the results under XVIII, the water alone being undetermined for want of material.

In the following table all the foregoing analyses of Norwegian material have been recalculated to the percentages found, excluding the insoluble matter, in order that their true relations may appear at a glance, whereby the sum of the rare earths combined is given instead of each earth or group of earths by itself. Only those constituents are tabulated which may be considered unquestionably in whole or in part as belonging to the uranium mineral. Silica, ferric or ferrous oxide as it may be, the small amounts of magnesia, alkalies, etc., may be thrown out as derived from admixed impurities. Lime from its close relationship to the other earths has been retained, though it is undoubtedly, in part at least, derived from foreign silicates.

TABLE V.—*Analyses of Norwegian uraninite recalculated.*

	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.
UO_3	32·04	25·48	26·04	32·50	35·69	42·11	27·12
UO_2	48·25	50·97	50·83	44·57	43·56	24·51	44·71
Earths	7·97	10·18	9·96	10·64	8·12	13·57	14·03
PbO	9·45	10·11	10·14	9·61	9·48	10·66	11·08
CaO	·39	·77	·45	·36	·41	1·07	·62
H_2O	·77	·73	*·87	·78	·79	1·23	?
N	1·23	1·28	1·28	1·05	1·08	?	1·26

*A portion of this water was perhaps derived from the large amount of foreign matter contaminating the uraninite.

An examination of analyses XII to XVI as recalculated above hardly allows of any other conclusion than that the specimens from the above four different quarries about Moss belong to one and the same mineral species. While analysis XII differs in some respects from Blomstrand's analysis of bröggerite, which is here reproduced in its original form and as modified by substitution of Fe_2O_3 for FeO, it simply serves to show, assuming correct analyses, that the mineral may vary in composition in the same quarry, for as before mentioned this is the original material from which Blomstrand made the species.

Blomstrand's bröggerite.

UO_3	38·82	36·31
UO_2	41·25	43·62
ThO_2	5·64	5·64
Y_2O_3	2·42	2·42
Ce_2O_3	·38	·38
CaO	·30	·30
PbO	8·41	8·41
FeO	1·26	Fe_2O_3 1·40
H_2O	·83	·83
SiO_2	·81	·81
	100·12	100·12

The estimation of UO_2, in the analyses of table IV, is thoroughly to be depended on, aside from the slight deduction to be made for possible ferrous oxide, while in view of the want of evidence as to the manner of filling his tubes with carbonic acid there is no guarantee that Blomstrand's figure may not be too low. Leaving out of consideration for the moment the nitrogen, it is clear in any case that the formula evolved by him from his analysis can not be derived from No. XII.

In regard to analyses XIII and XIV, there can exist no doubt whatever as to the identity of the material derived from Profs. Brögger and Nordenskiöld independently. A comparison of them with Lorenzen's analysis, coupled with the fact that not one of the specimens from the neighborhood of Moss above analyzed contains less than 8 per cent. of earths, gives rise to the strongest possible suspicion that that analyst has overlooked thoria altogether, notwithstanding the fact that the present material is from Elvestad and Lorenzen's[1] was from Huggenäskilen.

Lorenzen's uraninite.

UO_2	38·23	37·73
UO_3	50·43	50·89
PbO	9·72	9·72
FeO	·25	Fe_2O_3 ·28
CaO	·21	·21
H_2O	·70	·70
SiO_2	·31	·31
	99·84	99·84

Prof. Brögger, as above quoted (p. 68), says, however, that the material sent by him is to the best of his knowledge from the same place as that analyzed by Lorenzen, and this appears probable from the fact that the specimens from Huggenäskilen sent by Prof. Nordenskiöld show a totally different ratio between UO_2 and UO_3 (anal. XVI). If it should prove that Lorenzen erred in overlooking thoria, another of Blomstrand's supports in favor of the orthouranate formula for all uraninites, including bröggerite and cleveite, is knocked away, the first being the earlier and, as shown, incorrect analysis of Branchville uraninite.

The oxygen ratios calculated for analyses XII to XVI, counting all earths as thoria, whereby the comparison is very little affected since the percentages of the other earths are almost alike in all analyses, are as given below, as also the ratios for Blomstrand's bröggerite calculated from the second column on page 69 instead of the first in order to compare properly with the others.

[1] Nyt Mag. f. Naturv., vol. 28, p. 249.

	Mol. wt.	XII.		XIII and XIV.		XV.		XVI.		Blomstrand's bröggerite.	
UO_2	287	5·36	1	4·31	1	5·44	1	5·97	1	6·07	1
UO_3	271	5·70		6·01		5·26		5·14		5·15	
Earths	206	·96	1·37	1·21	1·85	1·28	1·33	·98	1·14	1·02	1·11
PbO	223	·68		·73		·69		·68		·60	

It is seen that none of the analyses conform even approximately to the ratio for Blomstrand's, except that of the mineral from Huggenäskilen. A recalculation of all on the basis of FeO for Fe_2O_3 and consequent changes in UO_2 and UO_3, and separation of the earths, would give the normal ratio 1:1 for Blomstrand's analysis, but the others would differ from it more widely than in the above exhibit.

The correctness of the orthouranate formula for bröggerite itself having been invalidated by the difference between his own analysis and anal. XII above, it is hardly worth while to discuss its applicability to the Bohemian and Saxon uraninites, of which no complete and reliable analyses seem to have been made, except perhaps the single one by Ebelmen in 1843 on Joachimsthal material, which on recalculation by Blomstrand was found to conform to his view. No more singular example can be furnished of incorrect conclusions founded on seemingly the best of evidence. No blame can attach to Blomstrand, but it can hardly be doubted that had he been able to analyze material from more than one quarry about Moss he would have seen the impossibility of reconciling the discrepancies in composition so as to admit of the application of one general formula.

It is apparent, notwithstanding the deficiency of earths and one or two other discrepancies, that analysis XVII was really made upon cleveite, as the label indicated. The density, too, corresponds almost exactly with that found by Nordenskiöld[1] and Lindström. In the latter's analysis, which is quoted below "water and a trace of CO_2" are given as loss on ignition, a result which under the circumstances must be considered unreliable.

The same objection applies to Hidden and Mackintosh's analysis of nivenite,[2] where it is stated plainly that the water represents loss on ignition. The analyses of cleveite and nivenite are here given together with XVII from table IV for convenient comparison. It may be mentioned that the 23·07 per cent of UO_2 in cleveite is the mean of two results differing by nearly 1½ per cent. Taking the higher as more nearly correct than the mean, almost exact agreement with the figures of analysis XVII for UO_2 and UO_3 is obtained.

[1] Geol. För. Förh., 1878, vol. 4, p. 28; Zeit. f. Kryst. vol. 3, p. 201.
[2] Am. Jour. Sci., [3] 1889, vol. 38, p. 481.

	Nivenite.	Cleveite.	XVII.
UO_3	46·75	40·60	41·71
UO_2	19·89	23·07	24·18
ThO_2	7·57	4·60	3·66
Ce_2O_3 etc.		2.25	
Y_2O_3 etc.	11·22	9 99	9·76
PbO	10·16	10 92	10·54
Fe_2O_3	·58	1·02	·03
CaO		·86	1·06
MgO		·14	*·33
SiO_2			·90
Ign	2·54	4·96	H_2O 1·23
Insol	1·22	2·34	1·10
CO_2 and N ?			5·50
	99.93	100·75	100·00

* And alk.

The appearance of cleveite is at once suggestive of alteration, and, in view of the uncertainty attaching to the water determinations for both nivenite and cleveite, it is probable that they represent nearly the same stage of alteration of the same species. What this species is is pretty clearly indicated by analysis XVIII of table IV, where the earths are in about the same proportions and total amounts as in XVII, but the UO_3 and UO_2 stand in a very different ratio. The material for this, as before said, came from Arendal, and presumably from the precise locality of the cleveite of analysis XVII, since the pieces of feldspathic rock containing them were in one package without distinguishing labels, but it was unquestionably fresher. The extreme solubility of this material compared with the other Norwegian uraninites is shared by that of analysis XVII, by cleveite, and by nivenite, and is to be explained probably not so much by advanced decomposition as by the preponderance here of a more soluble yttrium-uranium compound. Whether or not this last Arendal material is the source whence cleveite and its American representative have been derived by alteration, as seems most probable, it is in any event a true uraninite of more basic character than any of the Norwegian thorium-uraninites, and consequently conforms still less than those to the orthouranate formula.

BOHEMIAN AND SAXON URANINITE.

Nitrogen was carefully sought for in uraninite from Przibram, Joachimsthal, and Johanngeorgenstadt, using the apparatus figured on page 56. The extremely small bulk of gas finally obtained from all of them, after cleansing with potassium hydrate, measured about .2cm³ for Przibram and Joachimsthal, and much less for Johanngeorgenstadt, one gramme of mineral having been used. The above volume represents about ·02 per cent in weight of what can hardly be anything else than nitrogen.

None of the specimens contained zirconia, thoria, or other rare earths. Owing to the uncertainty of being able to determine with any close approach to truth the proportions of UO_2 and UO_3 in the presence of sulphides, and compounds of arsenic and vanadium of unknown degree of oxidation, no quantitative analyses have been carried out, but the attempt will yet be made to solve their composition.

DISCUSSION OF ANALYSES.

Hitherto the analyses have been considered in groups and without special reference to the nitrogen. It has been sought to show on grounds which would be valid even without its presence that the orthouranate formula is capable of no general application to uraninite, and that in the one or two cases where it does seem to apply this agreement is probably accidental. Taking into consideration the low atomic weight of nitrogen as compared with uranium, thorium, and lead, it is plain that it must play an important part in the constitution of the molecule, and that therefore its discovery alone, without other evidence furnished by the analyses, is sufficient to invalidate entirely the practically identical formulæ of Comstock and Blomstrand.

Throughout the whole list of analyses in which nitrogen has been estimated, the most striking feature is the apparent relation between the UO_2 and the nitrogen. This is especially marked in the second table of Norwegian uraninites (Table V), from which the rule might almost be formulated that, given either nitrogen or UO_2, the other can be found by simple calculation. The same ratio is not found in the Connecticut varieties, but if the imperfect determination of nitrogen in the Branchville mineral is to be depended on the rule still holds that the higher the UO_2 the higher likewise is the nitrogen. The Colorado and North Carolina minerals are exceptions, but it should be remembered that the former is amorphous, like the Bohemian, and possesses the further similarity of containing no thoria, though zirconia may take its place, and the North Carolina material is so much altered that its original condition is quite unknown.

In the absence of all positive knowledge whatever as to the rôle which nitrogen plays in the mineral, it would be idle to speculate at present upon the proper position of the latter in mineral classification. Much remains to be done before this question can be elucidated, but the general direction which the work must take can be fairly indicated.

But two explanations seem possible to account for the wide differences in the oxygen ratios for UO_3 and total bases, varying as they do from 1 : 4·37 for the Branchville material of analysis VI to 1 : 1 for Blomstrand's bröggerite, and even to a ratio indicating acidity for nivenite. Either all the others are alteration products of a mineral having the composition of the Branchville occurrence, or even of some unknown body entirely free from UO_3; or they are mixtures of two or more substances which need not necessarily be isomorphous, for Baumhauer's investi-

gations have shown that even well developed crystals of smaltite and chloanthite are often mechanical mixtures. Fractional solution might throw light on this point, and the following are the results of experimentation:

I. In one of the nitrogen estimations in Glastonbury uraninite by the original method the operation had to be discontinued before solution was complete. The undissolved residue, amounting after extraction of lead sulphate to 0·1234 gramme, was found to contain 71·94 per cent UO_2, the original percentage having been 59·93.

II. 1·095 grammes were boiled for 12 hours with dilute hydrochloric acid in a flask connected with a reversed condenser. The residue was 0·9193 gramme, showing that but 16 per cent had been dissolved, and it contained 64·66 per cent UO_2. The nitrogen was lost.

III. 2·012 grammes when boiled with the same hydrochloric acid for 42 hours afforded a residue of 1·4975, showing solution of 25·5 per cent. Its composition was—

UO_3	16·63	All U as UO_2 82·52.
UO_2	66·82	
Earths	10·81	
PbO	3·02	
N	2·67	
H_2O	(?)	
Insol	·37	
	100·32	

Here it is seen that the UO_2 has increased, and likewise the nitrogen, both in about the same proportion, but it is not clear why the earths and lead oxide should not show a greater change.

These experiments require repetition and extension to other than the Glastonbury mineral, but so far as they go they indicate that uraninite as we know it is not a single chemical substance, and that, as was to be expected in such case, the portion containing most UO_2 is the least soluble. They are not decisive as between the hypothesis of original mixture and that of mixtures resulting from alteration. In this respect the following observations are of interest. In dilute hydrochloric acid a large piece of North Carolina uraninite falls wholly to finest powder in course of time, which would hardly happen were it one original substance in process of alteration, unless the change affected every smallest particle of the mineral simultaneously and to the same extent. Hydrofluoric acid speedily covers the faces of a bright crystal of Branchville uraninite with a network of fine cracks visible only under the glass, and soon powder can be rubbed off with the fingers.

Whatever may be the eventual conclusion, it will be found that the small amount of water afforded by all analyses must be carefully considered. Small as this amount is, in consequence of its low molecular weight as opposed to uranium, thorium, and lead, it must play an im-

portant part in the mineral as a homogeneous whole or in one of its parts if a mixture. In the latter case it will unquestionably be found to belong to the more soluble component.

It is significant that the two uraninites highest in UO_2 give the lowest water, and while it is true that the Branchville mineral appears to contain more than that from Glastonbury, this may be only apparent, for the former was simply ignited in a current of air, while the latter was fused with sodium carbonate, and it is known that the vapors from both possess an acid reaction, and in the latter case give an increased weight to the calcium chloride tube when no alkaline carbonate is used. It is important that in all future analyses stress shall be laid upon the utmost accuracy in the water determinations, and if insoluble matter is present, it must be ascertained if possible how much, if any, of the water is to be ascribed to this source.

Before leaving this portion of the subject it is necessary to call attention to one difficulty presented by the analyses for which no satisfactory explanation yet presents itself. In the majority of cases in which all constituents have been estimated, the summation is considerably in excess of 100, and in some cases, where only one or two are wanting, it is evident that they would, if determined, produce a like result. Although it did not seem possible that this almost constant excess could be due to impurities from reagents, or to want of sufficient care in washing or igniting precipitates, it was determined to make an analysis on Glastonbury material with the utmost possible care, using specially prepared reagents and only platinum vessels and reducing the number of weighings to be used as the basis for the summation to a minimum. This analysis, executed partially in duplicate, is No. V, of Table I, and the excess still appears. It seems as if some one of the weighings must have been uniformly too high, but how this can be is a mystery. Efforts will still be made to find a solution. It can not be sought in a replacement of oxygen by nitrogen in combination with uranium, like the replacement of oxygen by fluorine in many minerals, for since the nitrogen is freed as a gas by sulphuric acid, it is immaterial, so far as the summation is concerned, whether the proportions of UO_2 and UO_3 as found by titration are correct or not. A certain amount of oxygen has been used, and, assuming its correct determination, it does not alter the result whether this has been employed to oxidize a suboxide of uranium to UO_3, supposing nitrogen to have replaced a part of the oxygen in UO_2, or only in oxidizing UO_2 to UO_3. In the former case the actual percentage of UO_3 in the mineral would be increased, but the oxygen consumed would be the same.

In a former notice[1] it was mentioned that a relation appeared to subsist between the nitrogen and the UO_2, but this statement was based on two experiments which subsequent work showed to be illusory. There is certainly a relation, but not exactly such a one as was

[1] Am. Jour. Sci., 1889, [3] vol. 38, p. 329.

then surmised. It was found, namely, on examining the portions used for water determinations (by ignition in dry air without sodium carbonate) for UO_2 and nitrogen, that the residual amounts of these were exactly in proportion to their original percentages, showing that the loss of nitrogen kept step with the oxidation of UO_2 to UO_3. It was later found that these results were accidental, for by sufficiently long heating the nitrogen was entirely eliminated, so far as the usual tests showed.

SPECIAL EXPERIMENTS RELATING TO THE NITROGEN IN URANINITE.

The last observation led naturally to a series of experiments as to the behavior of the nitrogen on heating in air, in carbonic acid, and in hydrogen, in the hope that thereby some clew might be obtained as to its probable condition in the mineral. They were all made on the material which had served for the final and most careful analysis of Glastonbury uraninite (No. V), not only because of the greater quantity at disposal, but also because of its high percentages in UO_2 and N. The results were in some respects perplexing to the last degree, and as yet no satisfactory explanation has been found. The mineral contained: UO_2 59·93, UO_3 23·03, N 2·41, H_2O 0·43, Fe_2O_3 0·29, total U as UO_2 81·67.

EFFECT OF HEATING IN AIR.

After ascertaining that no nitrogen could be obtained either by sulphuric acid or sodium-potassium carbonate when the mineral had previously been heated for a sufficient length of time in air, the following experiment was made to show if the final change in weight represented the difference between loss of water plus all nitrogen and gain of oxygen from oxidation of UO_2. The weight of ignited material, after determining water, in nearly all uraninites, had indicated that this could not be the case.

1·0028 gramme dried at 100° C.:

	gramme
When heated below redness gained	·0063
When heated at full redness for 6 hours gained	·0020
When heated at full redness for 6 hours gained	·0007
When heated at full redness for 6 hours gained	·0000
	·0090

Of the ignited product 1·0060 gramme equivalent to ·9970 gramme of unignited mineral, was decomposed in a sealed tube with dilute sulphuric acid. No nitrogen whatever was given off, and an amount of UO_2 was found representing 27·82 per cent of the unignited mineral. The UO_2 which had been oxidized to UO_3, therefore, was 59·93—27·82, or 32·11 per cent, which requires 1·90 per cent oxygen. The theoretical change in weight, assuming no nitrogen to have been expelled, would be the algebraic sum of the oxygen taken up, of the water driven off, and the small and uncertain additional loss which is shown by the

gain of a calcium chloride tube when no sodium carbonate is used in the water determination, and which amounts to about ·0012–·0015 g. This would be 1·90—(.43+.13), or 1.34. Assuming all nitrogen to have been expelled there should appear a *loss* of 1·07, and such a result was to be expected in view of the failure to find nitrogen in the ignited matter. The actual result would indicate that only 0·44 per cent of nitrogen had been expelled by prolonged heating. If this is so no other explanation seems possible than that the nitrogen has entered into some other state of combination in which it is not set free by sulphuric acid or by fusion with an alkaline carbonate.

It is of the highest importance to ascertain definitely if the nitrogen is given off in whole or in part by heating in an oxidizing atmosphere, but there are difficulties connected with the carrying out of such an experiment which have hitherto prevented its being made. It is intended, however, to try the experiment of heating in oxygen and absorbing the latter by chromous chloride, after the manner recommended by Jannasch and Meyer[1] for nitrogen determinations in organic bodies.

EFFECT OF HEATING IN CARBONIC ACID GAS.

I. 1.0722 gramme (dry) heated in carbonic acid generated from manganese carbonate lost 0.49 per cent in weight and afforded but a doubtful trace of nitrogen.

II. 1.0111 gramme (dry) when treated in a similar manner for a longer time, lost 0.69 per cent in weight, and gave, approximately, 1.4cm³ of gas or 0.17 per cent by weight of nitrogen. After several hours further heating the boat had lost no more in weight, and no additional gas seemed to be given off. Because of the impossibility of freeing the carbonic acid from all traces of atmospheric nitrogen—a copper roll having been used to retain its oxygen—it is impossible to say with any certainty whether small fractions of a cubic centimetre of gas were derived from the mineral or not.

EFFECT OF HEATING IN HYDROGEN.

The effect of heating in dry hydrogen was a reduction of practically all UO_3 to UO_2 and a slow expulsion of nitrogen; at least the usual methods showed less and less according to the duration of the heating. The following are the data obtained:

I. 1·1287 gramme (dry), after being heated for 3 hours in a combustion tube in a current of hydrogen purified by potassium hydrate and sulphuric acid, had suffered a loss of 0·0198 gramme. Of the ignited mineral 0·8022 gramme gave 1·62 per cent of nitrogen calculated to the original weight before reduction, and 0·3000 gramme required potassium permanganate equivalent to 81·18 per cent of UO_2 on the same basis. In view of the long heating required to reduce the percentage of nitrogen appreciably, it was not deemed practicable to collect any of it, because

[1] Ann. d. Chem., 1886, vol. 233, p. 375.

of the difficulty of getting rid of such a large quantity of hydrogen and the impossibility of freeing the latter entirely from atmospheric nitrogen. When transferred to a eudiometer and exploded with air and electrolytic oxyhydrogen the gas was found to be absolutely free from hydrogen, which it was thought might have resulted from the action of reduced iron on the acid. An evolution of hydrogen was observed at first, and the tube was not filled with carbonic acid till this had entirely ceased. The fact that not quite the theoretical amount of UO_2 was found indicates that reduction was not complete. More than the theoretical amount should have been found, owing to the ferrous iron formed on solution in acid.

It was proved by passing the gases from the combustion tube through dilute hydrochloric acid and evaporating the latter with platinic chloride that no ammonia whatever was formed.

The loss in weight above given should represent the water in the mineral (0·0049), the oxygen of the UO_3 reduced to UO_2 (0·0148), all the oxygen of the iron existing as ferric oxide, possibly the oxygen of lead oxide, and lastly an amount of nitrogen represented by the difference between the original percentage (2·41) and 1·62, the residual percentage. The water and the oxygen of the UO_3, however, alone amount to 0·0197, or just the total loss.

II. 1·5700 gramme (dry) gave a loss of 0·0316 gramme after six hours heating in hydrogen. 1·1179 gramme of the reduced mineral gave 1·05 per cent of nitrogen, and 0·4177 gramme gave 81·46 per cent of UO_2, both calculated to unreduced mineral. The loss in weight should represent 0·0067 water, 0·0206 oxygen from UO_3, an uncertain amount from Fe_2O_3 and possibly from PbO, and the difference between 2·41 and 1·05 per cent nitrogen. But it does not exceed the sum of water and oxygen alone, and as in the first experiment no nitrogen seems to have been removed, although quantitative tests show that much has disappeared. Further tests at a higher temperature in a crucible, whereby some lead was reduced and partly volatilized, showed that all the nitrogen could be caused to disappear.

These results are as perplexing as those obtained by heating in air, and the explanation when found will doubtless lead to one for the other case. The apparent failure to expel nitrogen by hydrogen might be taken as additional evidence of its combination with uranous uranium, but it is as difficult to conceive why it should not still be set free by sulphuric acid after reduction of the UO_3, as after oxidation of a portion of the UO_2 to UO_3.

CONCLUSIONS.

Briefly summarized the conclusions are as follows:

First. Nitrogen exists in uraninite in quantities up to over 2.5 per cent, and seems generally to bear a relation to the amount of UO_2 present. This is the first discovery of nitrogen in the primitive crust of the

earth, for the nitride of iron found by Silvestri[1] in lavas from Etna is of recent and secondary origin. It is rather strange that no works on mineralogy, so far as I am aware, make mention of his species.

Second. The condition in which the nitrogen exists is unknown, but it is entirely different from any hitherto observed in the mineral kingdom, being liberated as nitrogen gas by nonoxidizing acids and by fusion with an alkaline carbonate. Fusion with caustic alkalies does not give rise to the formation of ammonia, but probably liberates nitrogen.

Third. Analysis of uraninite from various localities has shown that, with in general the same constituents, the mineral varies widely in composition, and that its physical characteristics and its behavior toward certain solvents are often as distinct as the chemical differences.

Fourth. The formulæ of Comstock and Blomstrand are inapplicable to the zirconia, thoria, and yttria uraninites of North America and Norway, among which are to be reckoned bröggerite, cleveite, and nivenite, and probably to the varieties free from earths.

Fifth. Extended and most careful examination of uraninite specimens from all possible localities is necessary before any conclusion worthy of acceptance can be reached as to the character of the chemical combination, or combinations, represented by them. The work in this direction should likewise cover a study of the nitrides and oxynitrides of uranium and thorium, with synthetical experiments aiming at the artificial production of uraninite.

This latter work will probably be undertaken in this laboratory as opportunity may offer, together with some further experiments upon some of the material already examined. It is earnestly to be hoped that those possessing or in a position to procure uraninite specimens will take the trouble to examine them on the lines suggested in the foregoing pages, or if unable to do so, will kindly contribute material for examination here.

The interest in the matter is not confined merely to a solution of the composition of this one mineral; it is broader than that, and the question arises, may not nitrogen be a constituent of other species in a form hitherto unsuspected and unrecognizable by our ordinary chemical manipulations? And, if so, other problems are suggested which it is not now in order to discuss.

[1] Gaz. chim. Ital., 1875, vol. 5, p. 303.

METACINNABARITE FROM NEW ALMADEN, CALIFORNIA.

By W. H. Melville.

An excellent specimen of metacinnabarite was recently found in the quicksilver mine at New Almaden, Santa Clara County, California, and a portion of it was given me for examination. Metacinnabarite was never before known to occur in these deposits, although in neighboring cinnabar localities the amorphous mineral has been met with. This specimen carries finely developed and brilliant crystals which are admirably adapted for measurement on the goniometer.

In the ore seam where cinnabar has been deposited, there appears an argillaceous mass which has resulted from sediments derived from the decomposition of the country rock by solfataric action. This mass is not homogeneous but consists of gray and green particles, the former evidently a mixture of clay and partly decomposed rock constituents with a small amount of carbonates, the latter a silicate the composition of which in shown in the following analysis:

Analysis of the green silicate.

SiO_2	67·59
Cr_2O_3	5·31
Al_2O_3 } Fe_2O_3 }	12·24
NiO	4·57
CaO	0·73
MgO	7·84
Alkalies	very little
	98·28

In justice to these figures it should be said that only 0·1225 gramme of substance could be obtained in sufficient purity for study, and the little impurity which this sample contained could not be removed by Thoulet's solution; also alkalies could not be determined.

Throughout this sheet of soft argillaceous matter, or selvage, large quantities of metallic quicksilver easily seen by the naked eye are distributed, and bright red cinnabar often deeply coloring small areas of quartz has crystallized. Cinnabar is found mainly deposited on this

selvage—on the specimen at hand about an inch thick—intimately mixed with quartz, thus forming a hard compact mass upon which have grown cinnabar crystals, and these in turn are coated with minute quartz crystals. To this quartz the acute apex of the metacinnabarite crystal is attached and consequently is always broken. The genesis of this metacinnabarite was certainly subsequent to the deposition of the cinnabar, and groups of flat rhombohedrons of white semitransparent calcite appear to have formed at the same time. Crystallized dolomite is common among the ores of New Almaden and to this a fibrous silicate, undoubtedly chrysotile, firmly adheres. Fine bluish opal and occasional spangles of pyrite complete the list of associated minerals.

One other brittle substance was discovered while picking out metacinnabarite for analysis. It forms almost perfect spheres of a brilliant black color, which volatilize at a high temperature in yellowish vapor with a strong bituminous odor. The substance is organic matter, and curiously mercury does not enter into its composition. These spheres can be detected under the microscope embedded in the faces of the crystals of metacinnabarite (Fig. 2), and some were obtained by sharply rapping the specimen.

The rather low specific gravity of metacinnabarite is thus accounted for in part. Again, the presence of minute particles of quartz was unavoidable, and therefore the given value was also influenced to a slight extent by this cause. The crystals used for the determination of the specific gravity contained far less impurity than is recorded in the analysis which follows. The specific gravity was in two cases 7·095 and 7·142, or mean=7·118, almost identical with that of guadalcazarite, 7·15.

Analysis of metacinnabarite.

			At ratio.	
S	13·68		0·855	
Hg	78·01	S corresponding=12·48%	0·7801	
Fe	0·61	0·34	0·0218	0·0549
Co	trace			
Zn	0·90	0·44	0·0277	
Mn	0·15	0·09	0·0054	
$CaCO_3$	0·71			
Residue, quartz	4·57	13·35		
Volatile organic matter	0·63	S found ..... 13·68		
	99·26			

For analysis 0·6237 gramme of substance was available, and both the qualitative and quantitative study proceeded contemporaneously. The small errors of analysis are distributed between the sulphur and organic matter, where the sulphur is as usual a trifle too high. An uncertainty naturally exists in the determination of the organic matter. Selenium was looked for, but its presence was not established.

The crystals belong to the rhombohedral system (Miller) and consist of two poles differently modified. The following forms were observed:

Analogue pole.

	Miller.	Bravais-Miller. ($h\ k\ i\ m$)	Naumann.
Basal plane	$\varkappa(111)$	$\varkappa(0001)$	$c : \infty a : \infty a : \infty a$
Positive hemi-rhombohedron	$\varkappa(100)$	$\varkappa(1\bar{1}01)$	$c : a : a : \infty a$
Negative rhombohedron	$\varkappa(33\bar{2})$	$\varkappa(05\bar{5}4)$	$\frac{5}{2}c : \infty : 1 : 1$
Hemi-scalenohedron	$\varkappa(211)$	$\varkappa(1\bar{3}\bar{2}2)$	$\frac{3}{2}c : 3 : 1 : \frac{3}{2}$

Antilogue pole.

Negative hemi-rhombohedron	$\varkappa(33, \bar{1}\bar{7}, 17,)$	$\varkappa(50, \bar{5}0, 0, 1)$	$50c : 1 : 1 : \infty$
Hemi-scalenohedron	$\varkappa(31, 17, \bar{1}5)$	$\varkappa(48, 46, 2, \bar{1})$	$48c : 1 : \frac{2}{23} : 24$
Hemi-scalenohedron	$\varkappa(26, \bar{1}5, \bar{1}2)$	$\varkappa(41, 38, 3, \bar{1})$	$41c : 1 : \frac{3}{38} : \frac{41}{38}$

Angle of axes (Miller) = 118° 11′ 20″.

Axial ratio $c : a = 0{\cdot}2372 : 1$ (Naumann).

Measurements.

	Measured.	Calculated.
111 ∧ 100 =	15° 19′	
100 ∧ 010	26 29	
100 ∧ 21$\bar{1}$	4 15	
111 ∧ 33, 17, $\bar{1}$7	94 10	94° 10′ 36″
111 ∧ 31, 17, $\bar{1}$5	94 31	94 33
111 ∧ 26, $\bar{1}$5, $\bar{1}$2	94 42	95 17
33, $\bar{1}$7, 17 ∧ 17, 33, $\bar{1}$7	119 28	119 28
33, 17, $\bar{1}$7 ∧ 31, 17, $\bar{1}$5	2 6	
33, 17, $\bar{1}$7 ∧ 26, $\bar{1}$5, 12	3 55	

The poles of the scalenohedrons in the negative hemisphere almost belong in the zone circles passing through any two poles of the negative rhombohedron; therefore, as shown in the figures, the planes of the former do not exactly bevel the terminal edges of the latter. The faces of the former $\varkappa(26, \bar{1}5, \bar{1}2)$ are tectonic and contain series of reëntering angles (Fig. 2) which indicate the building up of that portion of the crystal rather than twinning. Otherwise striations are absent, and owing to the brilliancy of the plane surfaces sharp reflections of the signals on the goniometer were obtained. Fig. 2 was drawn with the aid of cross-hair and graduated stage of the microscope and in such position that the face (33, $\bar{1}$7, $\bar{1}$7) is parallel to the plane of projection. The following plane angles were read: $\alpha = 86° 20'$, $\beta = 82° 45'$, $\gamma = 39$, $\delta = 85° 30'$, $\eta = 24°$. The relations of these angles with the elements of the crystal have not been made out. With the exception of $\varkappa(33\bar{2})$ all the observed forms are represented in Fig. 1, and actually occur on one crystal with equal regularity. Fig. 2 is the combination of $\varkappa(111)$ with the planes of the antilogue pole tabulated above. The distances of the poles of all the rhombohedral faces from the pole of (111) were measured on the same crystals, and no doubt

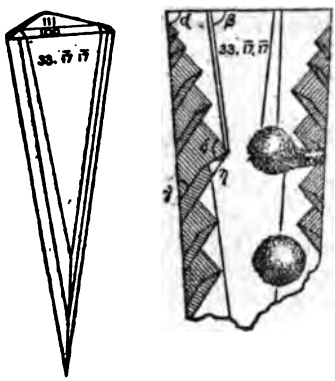


FIG. 2.—Metacinnabarite crystals.

can possibly exist as to the system of crystallization. Viewed as they are implanted on the rock, the crystals present much similarity to tetrahedrons, but examination shows that the face of the negative rhombohedron in combination with the basal plane forms an isosceles and not an equilateral triangle. Besides the measured angle $\beta=82°$ 45′ the plane acute angle of $(33, \bar{1}\bar{7}, \bar{1}7)=14°\ 29'\ 40''$ was calculated from the fundamental angles. The crystals vary in length from 1·24mm to 2·3mm and in width from 0·59mm to 0·97mm; possess a high metallic luster, black color, black streak with slight reddish tinge; are brittle with hardness about 2; and give the reactions for zinc and sulphide of mercury.

This mineral I consider metacinnabarite, since the atomic ratios give a very improbable formula. Its specific gravity is much below that given to the species by Mr. G. E. Moore[1] 7·70—7·75 for the reasons stated above. On the other hand its somewhat close resemblance to guadalcazarite[2] in chemical and physical properties—for Castillo mentions rhombohedral crystals of this mineral—might point to its identity with this species. But it must be acknowledged to be metacinnabarite in composition with a small percentage of impurity of other sulphides such as would be naturally expected on precipitation and crystallization from solution. Again, the crystals of metacinnabarite, many of which I have examined from localities in California as far back as 1882, are very indefinite, and although they appear to be rough cubo-octahedrons, might really consist of the combination of basal plane and rhombohedron. Mr. S. L. Penfield[3] has described metacinnabarite crystals from California, and determines them to be hemihedral isometric forms. One measurement is there given, viz: $322_{\wedge}3\bar{2}\bar{2}=86°\ 54\frac{1}{3}'$ (mean of three) which approximates the angle $(\bar{1}\bar{1}\bar{1})_{\wedge}(33, \bar{1}\bar{7}, 1\bar{7})=85°\ 50'$, the supplement of which appears in the table above. It is possible that these two planes may form the combination I have indicated. No angle occurs on crystals in my possession near that of $211_{\wedge}112=33°\ 15'$ to 36° 54′ which Mr. Penfield found. It is barely probable that metacinnabarite is dimorphous. If it should happen that brilliant crystals of metacinnabarite from the Knoxville quicksilver district should be found, I firmly believe that their habit could be reconciled with the symmetry of the crystals from New Almaden, the southern district.

It is through the kindness of Mr. Waldemar Lindgren, of the U. S. Geological Survey, and Mr. F. Von Leicht, the superintendent of the New Almaden quicksilver mines, that the material was available for this study.

[1] Dana's Mineralogy, App. I, p. 10. [2] Ibid, App. II, p. 25. [3] Am. Jour. Sci., June, 1885, p. 452.

AN APPARATUS FOR THE DETERMINATION OF WATER IN MINERAL ANALYSIS.

By Thomas M. Chatard.

In all cases where the water in minerals and rocks is easily expelled the apparatus described by me in the American Journal of Science, vol. XXXVII, June, 1889, p. 468, has been found very satisfactory. Many rocks and minerals, however, do not lose all of their water until exposed, for a considerable time, to a temperature at which glass softens. A more refractory tube is therefore necessary, and a platinum tube, such as is used for the determination of carbon in iron and steel, has been used to great advantage. The arrangement of the apparatus is shown in the cut.

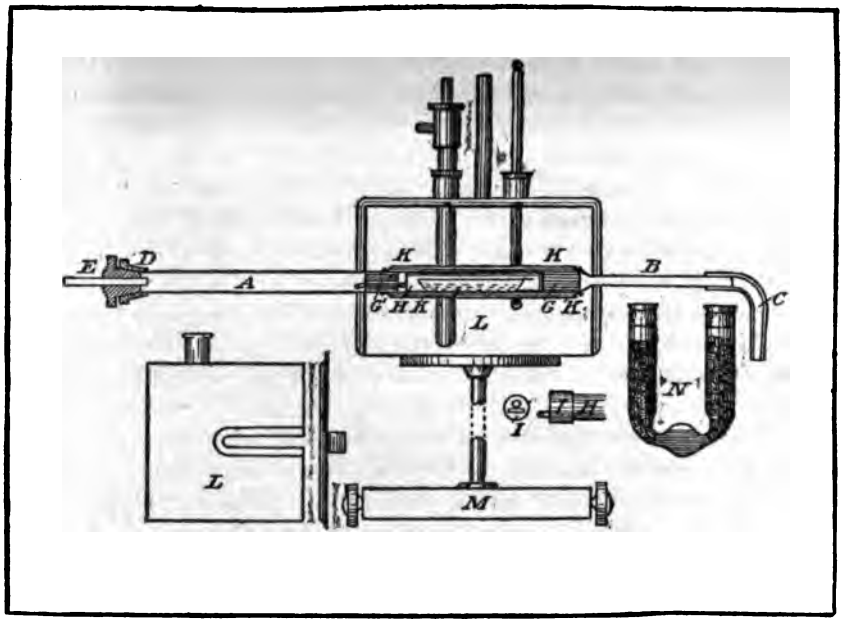


Fig. 3.—Apparatus for determination of water.

The tube A has an outside diameter of 16mm., the small tube B, 5mm. A need not be longer than 250—300mm., B, 80mm. C is a piece of lead glass tubing fused onto the end of B and bent and drawn out as shown.

D is a collar of phosphor bronze bored out with a slight taper and is fitted over the end of the platinum tube, the edge of which is flanged smoothly over the face of the collar. The phosphor-bronze plug E has a taper corresponding to that of the collar, which it fits very tightly and smoothly. The shoulders of both plug and collar are made hexagonal to insure a firm grasp when putting together or taking apart and should be stout enough to prevent any accidental deformation. The small tube F is closed at the inner end, a ring of small holes being bored through the side close to the face of the plug. By this arrangement all back circulation is prevented and the moisture which condenses in the cold part of the tube is easily and completely removed.

The platinum boat containing the substance to be examined is placed in a cylinder, H, made of platinum foil, which is closed at one end by a cap, I, in the center of which is a small hole to allow the passage of a current of air over the substance, while a small ring soldered to the cap enables one to put in or remove the cylinder with ease. The use of this cylinder prevents the loss of any of the substance by spattering, as when sodium carbonate is mixed with it, and also the frequently resulting adhesion of the boat to the tube.

The permeability of highly heated platinum to the gases of combustion, resulting in errors in the determination, is well known. To overcome this, and also to protect the valuable tube from injury, the part where the cylinder is placed, and which is ultimately exposed to the highest heat of a blast lamp, is wrapped with several layers of abestus paper soaked with a saturated solution of borax. The wrapping is secured with thread and thoroughly dried, more of the borax solution being put on if deemed necessary. When quite dry, the asbestus is covered with a sheet of platinum foil, KK, secured by wire. The whole is then highly heated and allowed to cool slowly. If properly made and put on, such a wrapping should last for months of steady use, can be easily replaced when necessary, and all risk of injury to the tube is avoided.

The air bath L, especially constructed for this tube, is a copper box open in front with a slit at each end, as shown in L′, suited to the size of the two portions of the tube. The front is closed by a plate of copper, on the inner side of which several layers of asbestus board are fastened. The edges of these are slightly beveled to insure a tight fit, and a hook at the top of the bath holds the plate in place. The bath is covered with asbestus board, and when in use the open portions of the slits are closed by asbestus plugs. The bath is furnished with thermostat, thermometer, and lamp, and the whole mounted on a stand, the base of which, M, is fitted with four small wheels so that it can be pushed into position or removed without disturbing the rest of the apparatus.

When using the apparatus the tube is fastened by a clamp near the end, the roll of platinum gauze G is shoved into place, the plug

inserted, a slow stream of dry air passed through, and then heated throughout its length and allowed to cool. The boat containing the substance is now put into the cylinder, which is at once pushed into the tube far enough to touch the roll of gauze. The roll G′ follows, and the plug is reinserted, the current of air being kept up. The air bath, previously brought to its standard temperature, 105°, is now opened, run into position, the tube sliding smoothly into the slits, and then closed, regaining its temperature in a few minutes. When it is considered that the tube and contents are perfectly dry, the U tube N, described in the paper already quoted, is attached, and the air bath removed by opening it and rolling it back. The tightness of the apparatus is now tested, and, if satisfactory, the air current is regulated and the tube gradually heated, beginning at the roll G′ and using an ordinary burner. If much water condenses in the bent glass tube the heat must be very gradually increased, and this is best effected by keeping the part G′ quite hot, thus heating the air current and preventing as far as possible the always annoying back circulation. Finally the portion of the tube covered by the borax asbestus is exposed to the full heat of a blast lamp, to which a flat burner has been adapted.

When no moisture remains in the glass tube the blast lamp is removed and the apparatus allowed to cool. When cold the U tube is disconnected and weighed and the cylinder with its contents withdrawn. If the amount of material at disposal is small, this portion can be used for the determination of the silica and the bases, since any loss has been prevented by the cylinder, which can be washed clean with dilute hydrochloric acid and any insoluble matter filtered off and added to the rest of the substance in the boat, which can be fused with sodium carbonate in the usual manner.

The use of the cylinder and the abestus wrapping obviates the only serious objection to this method, namely, the high cost of the platinum tube, as in this way the tube is absolutely protected from all damage. By having duplicate boats, cylinders, and U tubes the determinations can be made quite rapidly, and a large number of determinations made in this way by myself and others have given very satisfactory results.

THE SEPARATION OF TITANIUM, CHROMIUM, ALUMINUM, IRON, BARIUM, AND PHOSPHORIC ACID IN ROCK ANALYSIS.

By Thomas M. Chatard.

Having to examine some magnesian silicate rocks containing, in addition to iron and aluminum, small quantities of titanium, chromium, barium, and phosphoric acid, the methods for the decomposition of such rocks and the separation of their constituents were studied and compared so as to determine the most advisable manner of procedure. After repeated trials the following course, combining a number of well known methods, has been found to be the most satisfactory.

The silica and bases are determined by the ordinary sodium carbonate fusion method, in which the hydrates of titanium, iron, aluminum, and chromium, together with the phosphoric acid, are precipitated together and after weighing fused with sodium bisulphate, dissolved, the small amount of silica separated, and the solution, after reduction of the ferric oxide, titrated for total iron.

To separate these oxides and at the same time to determine the barium, two grammes of the finely pulverized mineral are put into a platinum crucible or dish, moistened with water, dilute sulphuric acid (1:1), and pure strong hydrofluoric acid added in considerable excess, the vessel put on a radiator to evaporate, and stirred from time to time. When the solution is so far evaporated that fumes of sulphuric acid begin to come off there should still be so much acid present as to form a solution or emulsion and not a paste, since the paste is liable to bake on the bottom of the vessel and form the difficultly soluble anhydrous sulphates produced by overheating, especially when magnesia is present in quantity. At this point it is well to add a few drops of nitric acid to oxidize the ferrous oxide and a little more hydrofluoric acid to insure the complete expulsion of the silica. The evaporation is then continued till the sulphuric acid fumes strongly and no odor of hydrofluoric acid can be detected when the solution is cooled below the point at which the sulphuric acid fumes.

Twenty-five cubic centimetres of dilute hydrochloric acid (1:5) is now added, stirring continually, and the material is then evaporated on the water bath till most of the HCl has been driven off. The

material is then washed into a beaker and any residue adhering to the vessel can be removed by a few drops of hot strong HCl, rubbing with a bit of paper if necessary. If the solution is very turbid it can be digested on the water bath for some time, but ultimately it is diluted with hot water to 250—300 cubic centimetres, allowed to stand for several hours, and then filtered.

The residue contains the barium as sulphate and sometimes small amounts of chromite or other minerals of the same class. It is washed, ignited, and thoroughly fused with sodium carbonate in a small crucible, the fused mass being then digested with hot water and leached. The well washed residue is dissolved on the filter with dilute HCl, and this solution filtered through the same filter, which after washing is burned, the ash fused with a little sodium carbonate, the mass dissolved in dilute HCl, and added to the leachings, which are now acidified, and added to the main solution after reduction of the chromic acid. The HCl solution containing the barium is evaporated to a few drops to get rid of the excess of HCl, taken up with water, and precipitated with dilute H_2SO_4. The filtrate from the barium sulphate is added to the main solution.

This main solution, which should be perfectly clear and contain the iron and chromium as sesquioxides, is now made alkaline by NH_4HO and the precipitate redissolved by dilute HCl. A few drops of acetic acid are added, the liquid brought to a boil, NH_4HO added in very slight excess, the boiling continued for a few minutes, and the precipitate filtered and washed. As the sole reason for this precipitation is to get rid of the magnesia and the accumulation of other salts, the washing need not be thorough but the filtrate must be tested and precipitation proved complete.

The precipitate is dissolved in hot dilute HCl. The filter, after washing, is burned in a large platinum crucible into which the solution, concentrated to a small bulk, is put and evaporated on the water bath till it becomes pasty. Just enough water is now added to dissolve the salts and then dry sodium carbonate is added in small portions, with continual stirring till a comparatively dry mass results. This must be very carefully done, for if too much soda is added at a time and each addition is not thoroughly stirred into the mass the after fusion is apt to be "lumpy" and unsatisfactory.

When a good excess of carbonate has been thus added the mass is dried and gradually brought to clear fusion, which should be continued for about half an hour. If lumps form, which is, however, rarely the case if lime and magnesia are absent and the foregoing directions are followed, they can be broken up by shaking the crucible with a circular motion to detach them from its walls. When the fusion is complete the mass is spread around the walls of the crucible and slightly cooled. A small quantity of sodium nitrate is now added, the whole rapidly fused and carefully boiled for not more than five minutes, again spread over

the crucible and rapidly cooled with a blast of air. The mass is boiled with water till completely disintegrated and then leached. Repeated tests have shown that the residue which contains the titanium is, when well washed, free from chromium and phosphoric acid.

The washed residue is dissolved in hot dilute HCl, the filter burned, the ash fused with $NaHSO_4$, dissolved in water and added to the solution. The titanium in this solution is separated by the excellent method of Dr. Gooch, following all the details as laid down by him in the Proc. Am. Acad., vol. 12, p. 435, et seq.[1] I have, however, found it convenient, after the destruction of the tartaric acid by potassium permanganate and the clearing of the solution by sulphurous acid, to add ammonia in slight excess, then at once acetic acid in excess, and boil with addition of sulphurous acid. The precipitate of titanium hydrate, mixed with some alumina, is filtered and washed with water containing sulphurous acid and a little acetic acid. It is thus freed from manganese and brought into a small compass, rendering the after work easier. Before the final precipitation of the titanium, the platinum, generally in the solution, should be removed by H_2S.

The filtrate containing the chromic and phosphoric acids is heated and ammonium nitrate cautiously added till no further precipitation of alumina occurs. The precipitation of the aluminum phosphate seems to be complete, but some alumina always remains in solution. The precipitate is allowed to settle, the supernatant liquid decanted, and the precipitate washed with solution of ammonium nitrate till the yellow tinge disappears; it is then dissolved in dilute HNO_3 and the phosphoric acid precipitated with molybdate solution.

The filtrate containing the chromic acid is acidified, boiled, neutralized with NH_4HO, and the chromic hydrate precipitated by freshly prepared ammonium sulphide. The precipitate, after some washing, is dissolved in hot dilute HNO_3, and after concentration, $KClO_3$ is added and the solution boiled, being finally evaporated nearly to dryness to expel the excess of acid. It is then diluted with cold water, and saturated solution of $NaHCO_3$ added in small excess separating the last traces of alumina. After standing about three hours the alumina is filtered off and washed with moderately dilute solution of $NaHCO_3$. The filtrate is acidified, and the chromic acid reduced, precipitated by ammonium sulphide, filtered, washed, redissolved to get rid of traces of alkali, reprecipitated, and finally weighed as Cr_2O_3.

This method, due to Baubigny, for the separation of chromium from aluminum is very good and convenient if the solution is free from iron and contains but little alumina. Careful tests have shown that if iron is present some of it always remains in solution, while if there is much alumina, it is almost impossible to wash out the chromate from the bulky precipitate with the cold solution of $NaHCO_3$, which must be used. It must also be noted in this connection that a solution of iron

[1] Bull. 27, U. S. Geol. Surv., p. 16, et seq.

and chromium, prepared by the Baubigny method, was made ammoniacal, and it was proved that while all of the iron was precipitated, this precipitate, even after the most careful washing with hot water, contained chromium.

Although the number of details in this process may seem very great, experience has shown that none of them can be safely neglected for the purpose of shortening the work; if the whole process is carefully followed out, the results are very satisfactory, as shown by the following tests on a typical magnesian rock:

	Cr_2O_3.	TiO_2.	BaO.	P_2O_5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
No. 1	0.270	0.46	0.040	0.375
No. 2	0.295	0.39	0.060	0.395
No. 3	0.217	0.46	0.055	.....
No. 4	0.280	.....	.....	.....
Average	0.268	0.44	0.053	0.380

The use of niter for the fusions is not absolutely necessary, though one is more sure of complete oxidation. In the analysis of chrome ores, the best results have been obtained by fusing the finely pulverized ore with sodium carbonate alone, but keeping it in clear fusion for an hour. The fused mass is treated like an ordinary silicate fusion, the silica, after weighing, being volatilized by HFl, and the residue, usually small, again fused with Na_2CO_3. This second fusion gives a clear solution in HCl.

SEVEN NEW METEORITES.

By L. G. Eakins.

STONY METEORITE FROM TEXAS.

The meteorite which forms the subject of this article was found in Travis County, Texas, and brought to notice by Prof. R. T. Hill, of the University of Texas, who presented the piece first obtained by him to the National Museum. This piece, of an irregular shape and weighing about 2½ kilograms, is supposed to be but a fragment of a much larger mass which Prof. Hill expects to obtain.

It has a superficial coating of a yellowish brown color where it has been subject to weathering, but on a fractured, unaltered surface it is dull black with a slight grayish tinge. It is hard, compact, and very tough; to the unaided eye the stony mass is very uniform in structure, and none of the composing silicates can be distinguished, but troilite can be plainly seen scattered throughout it, and on a ground and polished surface the metallic particles are also visible. Under the microscope, (for which information I am indebted to Mr. Whitman Cross,) the stony portion seems to consist chiefly of olivine and enstatite, with a small quantity of a colorless mineral which is probably a feldspar; as will be seen later, the analytical results also indicate the presence of a feldspar, while chromite also was found unmistakably.

The mass has a specific gravity of 3·543 at 30°, and its analysis as a whole is as follows:

SiO_2	44·75
Al_2O_3	2·72
Cr_2O_3	·52
Cu	tr.
FeO	16·04
Fe	1·83
NiO	·52
Ni	·22
Co	·01
MnO	tr.
CaO	2·23

MgO	27·93
K_2O	·13
Na_2O	1·13
P_2O_5	·41
S	1·83
H_2O	·84
	101·11
Less O for S	·92
	100·19

From some of the finely powdered material the metallic portion was extracted by the aid of an electromagnet, and as slight amounts of troilite and the silicates remained attached, this was then treated with a neutral solution of copper sulphate and the solution analyzed. This gave the metallic part as constituting 2·23 per cent of the mass, with the following composition, calculated to 100 per cent:

Fe	88·74
Ni	10·68
Co	·58
	100·00

The residue from which the metallic portion had been removed was then digested with dilute hydrochloric acid; this dissolved the troilite and olivine, and the soluble and insoluble portions were then separated and analyzed in the usual manner. The sulphur present was calculated as troilite, with the formula FeS, and has been deducted in stating the analysis of the soluble portion:

	Soluble in HCl. (Troilite deducted.)			Insoluble in HCl.		
	Analysis.	Calculated to 100 per cent.	Molecular ratios.	Analysis.	Calculated to 100 per cent.	Molecular ratios.
SiO_2	15·67	38·13	·636	30·36	56·14	·936
Al_2O_3	1·06	2·58	·025	2·02	3·73	·036
Cr_2O_3	.....	.....	.....	·54	1·00	·007
FeO	8·12	19·76	·274	4·95	9·15	·127
NiO	·49	1·19	·016	.....	.....	.....
CaO	·42	1·02	·018	1·94	3·59	·064
MgO	15·34	37·32	·933	13·22	24·44	·611
K_2O	undet.	.....	.....	·10	·19	·002
Na_2O	undet.	.....	.....	·95	1·76	·028
	41·10	100·00	.....	54·08	100·00	.....

In the soluble portion the ratio of the RO group to the SiO_2 is as close to that of olivine as could be expected in work of this kind. The insoluble portion, after removing the Cr_2O_3 and a proportional amount of FeO to form chromite, gives these ratios:

$$RO : Al_2O_3 : SiO_2$$
$$·825 : ·036 : ·936,$$

which seem to bear no definite relations to each other. It is noticeable, however, that the Al_2O_3 and alkalies present are nearly in the proportion required for a feldspar, and if one of the oligoclase type were present in proportion to this Al_2O_3, it would have these molecular values:

$$RO : Al_2O_3 : 4\tfrac{1}{2}\ SiO_2$$
$$\cdot 036 : \cdot 036 : \cdot 162;$$

assuming this to be the case, and deducting this amount of feldspar, it would leave

$$RO : SiO_2$$
$$\cdot 789 : \cdot 774,$$

which corresponds closely to enstatite.

By calculating the soluble and insoluble parts as having been determined on the original material minus the metallic portion and water, and taking all the sulphur as representing troilite (FeS), the general composition of the meteorite is shown to be

Metallic	2·23
Troilite	5·03
Soluble in acids	39·84
Insoluble in acids	52·42
	99·52

METEORIC IRON FROM NORTH CAROLINA.[1]

The iron here described was found in the latter part of 1880 on a farm near Ellenboro', Rutherford County, North Carolina, and its nature remained unknown until February, 1890, when it was brought for examination to Mr. Stuart W. Cramer, of the United States assay office at Charlotte, North Carolina, who ascertained that it was a meteorite and obtained half of the mass. This portion was sent by Mr. Cramer to the U. S. National Museum for description, and the iron was cut and divided between the Museum collection and that of the assay office.

The weight of the original mass, as near as can be determined, was about 2,200 grammes; in shape it was roughly two globular ends with a connecting bar the total length being about 150mm., with end of diameters of 75mm., and 50 mm. in the middle.

The iron is very tough and highly crystalline; the Widmanstätten figures show distinctly on a polished, unetched face, and after etching they are unusually strong. Small, irregularly distributed patches of troilite are visible, and schreibersite also seems to be present. On account of the small amount of material that could be obtained for analysis no attempt was made to determine carbon, and the sulphur found shows that very little troilite happened to be included in the material analyzed, which, of course, in such highly crystalline material could not represent the actual average composition without cutting up a large part of the mass.

[1] Am Jour. Sci., May, 1890, vol. 39.

The analysis is as follows:

Fe	88·05
Ni	10·37
Co	·68
Cu	·04
P	·21
S	·08
Si	·02
	99·45

PALLASITE FROM KANSAS.

This is one of a group of meteorites found in Brenham township, Kiowa County, Kansas, and fully described by Mr. G. F. Kunz in Science, vol. 15, No. 384, and American Journal of Science, vol. 40, October, 1890.

First plowed up by the farmers some years ago, it was not until March, 1890, that their meteoric nature was discovered; there are now known to be about twenty in all, with an aggregate weight of 2,000 pounds, and ranging individually from 466 pounds to 1 ounce.

There are two distinct groups; one of the more common nickeliferous irons of highly crystalline structure, the other of the form known as pallasite, a meteoric iron containing olivine. It is one of the latter group that forms the subject of this article. In it the olivine scattered throughout the iron is roughly in two zones, an inner one of clear, brilliant material; and an outer one which is very dark, almost black in places, consisting, as was shown by the analysis and microscopical examination, of an intimate mixture of olivine and troilite.

In procuring material for the analysis of the olivine, transparent clear yellow crystals or fragments were carefully picked out, and for the dark zone care was taken to get as uniform material as possible. In addition to being in the dark olivine zone, troilite is scattered throughout the metallic iron, the iron on etching showing the Widmanstätten figures. The specific gravity of the iron free from olivine is 7·93 at 23·4° C., and of the pure olivine 3·376 at 23·2° C. The analyses are as follows

Iron.		Olivine.		Dark outer zone.	
Fe	88·49	SiO_2	40·70	SiO_2	34·14
Ni	10·35	Al_2O_3	tr.	FeO	23·20
Co	·57	Fe_2O_3	·18	NiO	tr.
Cu	·03	FeO	10·79	CoO	·03
P	·14	NiO	·02	MnO	·09
S	·08	MnO	·14	MgO	40·19
C	tr.	MgO	48·02	S	5·42
Si	tr.		99·85		103·07
	99·66			Less O for S.	2·71
					100·36

METEORIC IRON FROM TEXAS.

This iron was received from Mr. E. E. Howell, who has published a description of it and the one following (from Puquios, Chili) in the American Journal of Science, vol. 40, September, 1890. It was found in Hamilton County, Texas, although first credited to Erath County, of that State.

Its original weight was about 81½ kilos, and its greatest dimensions 44 by 33 centimetres. A polished face of this iron plainly shows the crystalline structure, and on etching the Widmanstätten figures are of unusual beauty.

It has a specific gravity of 7·95 at 27° C. and furnished the following analysis:

Fe	86·54
Ni	12·77
Co	·63
Cu	·02
P	·16
S	·03
C	·11
	100·26

METEORIC IRON FROM CHILI.

This meteorite was found near Puquios, probably about 1885, and kept in Chili until 1889, when it came into the possession of Prof. H. A. Ward. Its weight was about 6½ kilos, and its greatest dimensions 25½ by 14 centimetres. The most noticeable feature of this iron is the faulting phenomenon, which is shown on the etched sections, and is fully described by Mr. Howell in the article referred to. Specific gravity, 7·93 at 25·2° C. Analysis:

Fe	88·67
Ni	9·83
Co	·71
Cu	·04
P	·17
S	·09
Si	tr. (?)
C	·04
	99·55

CHONDRODITE FROM IOWA.

An account of this meteorite is given in detail in the American Journal of Science, vol. 40, October, 1890, in an article by Mr. G. F. Kunz, who furnished the material on which this analysis was made. It fell on May 2, 1890, in Winnebago County, Iowa, the various fragments being scattered over a considerable area, while a part of the mass is believed to have passed over into Minnesota. The stone is somewhat porous, and

on a fractured surface is spotted gray in color, showing visible particles of iron and of troilite.

The specific gravity of the mass is 3.804 at 28.5° C., and on analysis it yielded these results:

Approximate composition of the mass.		Analysis of the nickeliferous iron.	
Nickeliferous iron	19·40	Fe	93·05
Troilite	6·19	Ni	6·11
Silicates soluble in HCl	26·04	Co	·65
Silicates insoluble in HCl	38·37	P	tr.
			99.41

Analysis of the siliceous portion, with all magnetic extracted.

Soluble in HCl.				Insoluble in HCl.		
	(1)	(2)	Calculated to 100 per cent. (3)		(4)	Calculated to 100 per cent. (5)
SiO_2	17·82	17·82	39·74	SiO_2	26·49	55·51
FeO	*14·27	8·26	18·42	Al_2O_3	2·50	5·43
NiO	·17	·17	·38	Cr_2O_3	·12	·25
MnO	trace.	trace.		FeO	4·49	9·45
CaO	·31	·31	·69	NiO	trace.	
MgO	18·28	18·28	40·77	CaO	1·45	3·03
Alk	trace.	trace.		MgO	11·50	24·09
S	†2·67			K_2O	·07	·15
P	trace.	trace.		Na_2O	1·01	2·12
	53·52	44·84	100·00		47·72	100·00
O for S	1·34					
	52·18					

*Taking out 6.01 FeO equivalent to 4.67 Fe required by S to form FeS.
†Taking out S to form FeS.

The analyses numbered from 1 to 5 were made on the residue left after extracting all the magnetic material. No. 1 is the portion soluble in HCl; No. 2, that insoluble in HCl, the two added together giving the analysis of the non-magnetic portion as a whole. No. 2 is the same as No. 1 after deducting the S and a corresponding amount of FeO equivalent to the Fe necessary to form troilite with the S. No. 3 is No. 2 calculated to 100 per cent. No. 5 is No. 4 calculated to 100 per cent. The Cr_2O_3 probably represents chromite, and the alkalies and alumina with a little lime may come from a soda lime feldspar.

The method employed to determine as closely as possible the composition of the mass of this and similar meteorites is to extract everything possible with an electro-magnet; this removes all the nickeliferous iron and a little troilite, leaving the siliceous part and most of the troilite. The S present in the magnetic portion and that in the siliceous

portion is calculated as FeS, and in stating the analysis of the nickeliferous iron the slight amount of attached troilite and silicates is first deducted. The silicates are split up by HCl as above, and from the different weights found the approximate composition is calculated.

LLANO DEL INCA METEORITE.

Fragments of this meteorite amounting to 27 pounds were obtained by Prof. Ward in 1889, they having been found the previous year 35 leagues southeast of Taltal, Atacama, Chili, on the Llano del Inca. Mr. E. E. Howell has described this meteorite in the proceedings of the Rochester Academy of Science, vol. 1. It consists of a mixture of iron and stone, superficially of a dark brown color, the fresh polished surface showing the iron scattered all through the stony mass.

Analyses.

Approximate composition of the mass.		Analysis of the nickeliferous iron.	
Nickeliferous iron	25·8	Fe	89·77
Troilite	10·6	Ni	9·17
Silicates soluble in HCl	30·9	Co	·61
Silicates insoluble in HCl	32·6		99·55

Analysis of the siliceous portion, with all magnetic extracted.

Soluble in HCl.				Insoluble in HCl.		
	(1)	(2)	Calculated to 100 per cent. (3)		(4)	Calculated to 100 per cent. (5)
SiO_2	11·53	11·53	28·08	SiO_2	23·15	53·11
Al_2O_3	5·23	5·23	12·74	Al_2O_3	1·01	2·32
FeO	*28·89	17·46	42·52	Cr_2O_3	·39	·90
NiO	1·19	1·19	2·90	FeO	8·20	18·82
MnO	·08	·08	·20	CaO	·76	1·75
CaO	3·83	3·83	9·33	MgO	10·07	23·10
MgO	·81	·81	1·98	P_2O_5	trace.	
P_2O_5	·93	·93	2·25		43·58	100·00
S	†5.08					
	57·57	41·06	100·00			
— O for S	2 54					
	55·03					

* Taking out 11.43 FeO equivalent to 8.89 Fe required by S to form FeS.
† Taking out S to form FeS.

ON A PETROLEUM FROM CUBA.

By H. N. Stokes.

At Santa Clara, Cuba, there is a spring known as the Sandalwood Spring, from which issues with the water a certain amount of petroleum, which, from its peculiar odor, is called "sandalina," or sandalwood oil, although it more closely resembles the odor of cedar. The oil is collected from the surface of the water, and used as illuminating oil and for other purposes without being refined. About two litres of this oil were sent to the laboratory of the U. S. Geological Survey by Mr. C. W. Cunningham, and its examination gave the results described below.

The oil, which is about as viscous as strong sulphuric acid, is somewhat turbid from suspended water, but when dried over calcium chloride it is perfectly transparent, amber colored, and shows the merest trace of bluish-green fluorescence. Its odor, as above mentioned, is agreeable, and in no way suggestive of even refined American petroleums, but rather of cedar wood. The specific gravity at $\frac{33}{33}$° is 0.901.

A single distillation, with simple distilling bulb, gave the following fractions in parts per hundred by weight:

Under 250° C	3.3	
250–260°	6.0	
260–270°	11.2	
270–280°	12.1	
280–290°	16.6	
290–300°	18.0	
300–310°	8.4	Over 300°, 32.8.
310–330°	13.1	
Residue	11.3	

The most noticeable feature of this table is the small amount boiling under 250° and over 300°. Engler and Levin[1] give a similar table for nine petroleums from different sources, none of which shows a similar composition. The first fraction passed over entirely between 230° and 250°, only a slight escape of gas being noticed below this point. The absence of volatile constituents is perhaps due in part to evaporation before collecting, but this does not explain the small amount of high boiling portions. The fractions under 290° were colorless, and those

[1] Dingl. Polyt. Jour., 1886, vol. 261, p. 32. Post, Chem.-techn. Anal., 2te Aufl., vol. 1, p. 267.

from 250° to 270° possessed a peculiar camphor-like taste, but the characteristic odor was entirely lacking in the distillates. The residue boiling above 330° was dark, oily, and opaque, and when hot had a very irritating odor. The specific gravity of the fraction under 250° at $\frac{33}{33}$° was 0.855, and that of the residue boiling above 330° was 0.941.

The absence of *sulphur* compounds was to be inferred from the absence of disagreeable odor, which was confirmed by boiling a long time with metallic sodium and treating the product with sodium nitroprusside,[1] whereby not the slightest trace of a sulphur reaction could be obtained.

The carefully dried oil contains little but hydrocarbons, as shown by the elementary analysis:

	I.	II.
C.....	86.90	86.64
H.....	12.75	12.48

This leaves a margin of only 0.6 per cent for oxygen, nitrogen, and other substances. Shaking out with alkali, acidifying the latter, and extracting with ether gave the merest traces of residue, from which the absence of phenols and acids follows.

The fraction boiling under 250° gave—

C 86.76.

H 13.05.

The classes of hydrocarbons thus far recognized in petroleum are, as is well known:

1. *Paraffins*, C_nH_{2n+2}.
2. *Olefins*, C_nH_{2n}, and still more unsaturated fatty hydrocarbons.
3. *Aromatic hydrocarbons.*
4. *Naphthenes*, C_nH_{2n}, which, so far as their structure is understood, are perhydrides of aromatic hydrocarbons, or hexamethylene derivatives, with hydrocarbons containing more carbon,[2] but showing the same general properties, and probably related to the naphthenes C_nH_{2n}, as naphthalene, diphenyl, etc., to benzole; that is, containing several single or double hexamethylene rings.

With the small amount of oil at my disposal it was impossible to attempt to isolate any hydrocarbon in a pure state by fractioning, and I had to satisfy myself with general reactions indicating the presence or absence of the different groups. In fact, a high boiling petroleum like sandalina would contain so many closely allied bodies of nearly identical boiling points, that their separation would be at best an extremely tedious and difficult operation, especially as so little is known of the nature of petroleum hydrocarbons boiling over 250°.

[1] Vohl, Dingl. Polyt. Journ., vol. 216, p. 47.

[2] Markownikoff, Liebig's Annalen, vol. 234, p. 115.

PARAFFINS.

The higher paraffins, constituting paraffin wax, are apparently entirely absent from sandalina, as not the slightest deposit was obtained by cooling in a freezing mixture, with or without addition of ether, either from the oil itself or from the residue boiling above 330°. In either case the only result was a slight increase of viscosity. No grounds could be found for assuming the presence of liquid paraffins; for, as shown below, the the oil seems to be entirely destroyed by continued action of fuming sulphuric acid, no residue being obtained which shows greater resistance towards this reagent than the oil itself.

UNSATURATED FATTY HYDROCARBONS.

These bodies, which are found in greater or less quantity in most petroleums, are almost entirely absent from sandalina, as shown by its inertness toward bromine, which is so readily absorbed by bodies of the ethylene, acetylene, and similar series. Careful bromine absorptions[1] were made with the following results. The figures indicate the weight of bromine absorbed by 100 grammes of oil:

Fraction under 250°	0.86
250°–270°	0 25
270°–290°	0.87
290°–310°	0.72
310°–330°	1.34
Residue above 330°	1.72
Sandalina, undistilled	0.80
Absorbtion of sandalina calculated from absorption of the fractions	0.83

For comparison, a sample of refined burning petroleum gave 2.69, and fine white paraffin 0.53. Remembering that under the conditions of the experiment bromine exercises a slight substituting action even on saturated hydrocarbons, and that the absorption found for sandalina corresponds to only 1.75 per cent of a hydrocarbon $C_{25}H_{50}$, and proportionally less of lower or more unsaturated bodies, it is safe to say that the unsaturated hydrocarbons do not exceed 1 per cent.

AROMATIC HYDROCARBONS.

A mixture of concentrated nitric and sulphuric acids attacks sandalina quite readily, forming notable quantities of nitro compounds, for the most part soluble in alkali. This is not an indication of the presence of aromatic bodies, as naphthenes are oxidized by nitric acid, with formation of small quantities of aromatic nitro compounds.[2] Aromatic hydrocarbons are now usually sought for by first separating the constituents as perfectly as possible by fractional distillation, and then treat-

[1] Allen, Commercial Organ. Anal., 2d ed., vol. 2, p. 331.

[2] Markownikoff, Liebig's Annalen, vol. 234, p. 91. Markownikoff and Spady, Ber. deutsch. chem. Gesell., Jahrg. xx, p. 1850.

ing each fraction separately with fuming sulphuric acid, which converts the aromatic hydrocarbons into sulphonic acids, which are separated by means of their salts, only those being sought whose hydrocarbons boil within the limits of the fraction.[1] Whether a sulphonic acid thus obtained is positive proof of the presence of the aromatic hydrocarbon rather than of the corresponding naphthene may be questioned,[2] but the absence of the acid may be regarded as proof of the absence of the aromatic body. This at least is true of the portions boiling below 250°; whether it applies to oils of such high boiling range as sandalina might be doubted.

In this case it was not possible to carry out a systematic fractioning, so I attempted to obtain only bodies having the general characteristics of aromatic sulphonic acids, or rather, of their salts. In two series of experiments, in which sandalina itself and the residue boiling above 300° were used, the oil was first shaken out with concentrated sulphuric acid, and then repeatedly with fresh portions of a mixture of equal parts concentrated sulphuric acid and crystallized pyrosulphuric acid, 10 per cent of the volume of the oil being used each time. The latter produced considerable rise of temperature, with evolution of sulphur dioxide. As soon as no further action was observed, the black tarry acid was drawn off and the process repeated. The action of the acid did not decrease in violence even after many such operations, and in one experiment nearly the whole of the oil went into solution without leaving a residue which acted differently from the sandalina itself. Crystalline pyrosulphuric acid acted with still greater violence, causing a rise of temperature of 20°. The acids were united, and after dilution, which gave dark amorphous masses slowly dissolving in water, were neutralized with caustic potash or barium carbonate, and the sulpho-salts sought for by appropriate means. Only in the case of the residue boiling above 300° were obtained 5 grammes of a barium salt of resinous appearance, dissolving to a sirup in water and totally destroyed by nitric acid with production of barium sulphate. It showed no resemblance to the aromatic sulphonates, and hence, so far as the method holds good in this case, aromatic hydrocarbons are absent. What substances are actually formed by the action of the acid was not determined, as their exceedingly disagreeable properties made such an examination undesirable.

NAPHTHENES.

Aromatic bodies were further sought for by oxidizing sandalina with chromic acid, hoping thus to obtain aromatic acids, which would at least indicate the presence of aromatic hydrocarbons. The result was in this case also negative, no such acids being obtained, even after total oxidation of the oil. Products of a totally different nature were, however, found, which threw some light on the nature of the bodies present.

[1] Markownikoff, Liebig's Annalen, vol. 234, p. 92.

[2] Markownikoff and Spady, Ber. deutsch. chem. Gesell., Jahrg. xx, p. 1853.

Chromic and glacial acetic acid attack sandalina violently, forming products of peculiar odor, which were not further studied.

Sandalina is attacked only by strong chromic acid mixture; 150 grammes oil, boiled with 300 grammes potassium bichromate, and 450 grammes sulphuric acid, diluted with 2 volumes water, was scarcely affected; 150 grammes sandalina, 400 grammes bichromate, and 600 grammes strong sulphuric acid, diluted with 1½ volumes of water, were boiled in a flask admitting of the observation of the escaping gas, the collection of the distillate, and the replacement of the escaping water. From time to time the operation was interrupted, the oil shaken out with dilute alkali, and returned to the flask with fresh oxidizing mixture. After four oxidations the oil was practically all destroyed. The characteristic odor of sandalina was observable during the whole operation. The distillate, which was acid, smelled strongly of acetone, which after neutralizing was distilled off and recognized by the copious yield of iodoform with alkaline iodine solution. The distillate yielded 35 grammes of a potassium salt, which by appropriate fractioning was found to consist essentially of acetate, with traces of higher homologues. By far the greater portion of the acetic acid remained in the oxidizing mixture. By extracting the latter with ether, a small quantity of a sirupy acid was obtained, which deposited some crystals. Silver salts were prepared by fractional precipitation, but analysis of these gave no definite formula, and the quantity was too small to attempt to purify further.

The alkaline solutions obtained by extracting the oil during oxidation were united and acidified, whereby a mixture of oily acids separated.[1] It was purified by neutralizing, precipitating the lead salts, dissolving these in ether, and regenerating the acids. Thus treated, it formed a colorless oil of peculiar odor, which adhered very persistently to the person. It was obviously a mixture, and the comparatively small quantity did not admit of separation, but its properties indicated sufficiently to what class of acids its constituents belonged. It dissolved in alkali, but the solution was precipitated by excess of strong alkali, and also by dilution, in case no free alkali was present, whereby a solid acid salt and free alkali were formed. The potassium salt formed a mass of the consistency of soft soap, and foaming strongly with water.

The *barium* salt was a sirup, insoluble in water, difficultly in alcohol, but readily in ether.

The *silver* salt was white, amorphous, and always contained free acid, which could be removed by ether, with partial solution of the salt itself.

The *lead* salt was a pasty, amorphous mass, completely fusing under warm water, and very soluble in ether.

The *ethyl ester*, prepared from the silver salt, was an oily liquid of very pleasant fruity odor.

[1] Extraction with alkali proved the entire absence of bodies of acid nature in the unoxidized oil.

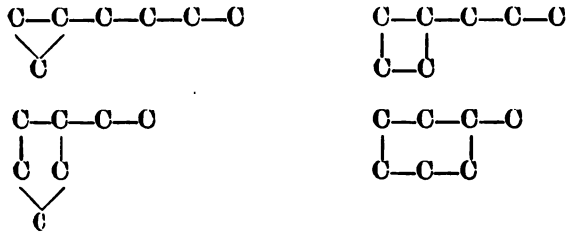
The acid (or rather mixture of acids) is not acted on in the slightest degree by bromine, a fact which distinguishes it sharply from the higher unsaturated fatty acids, such as oleic acid, which it resembles in the solubility of its easily fusible lead salts in ether. It is easily oxidized by chromic acid, forming apparently more volatile acids of the same nature, and acetic acid.

The above properties identify the acids in question with the *petroleum* or *naphthene* acids found by Hell and Medinger[1] in the alkaline waste from refining Wallachian petroleum. The following acids of this series have been isolated:

$C_7H_{12}O_2$[2], $C_8H_{14}O_2$[3], $C_9H_{16}O_2$[3]. $C_{11}H_{20}O_2$[4], $C_{12}H_{22}O_2$[4], $C_{13}H_{24}O_2$[5], $C_{15}H_{28}O_2$[6].

All these acids show the same general properties as those obtained from sandalina. Similar acids were obtained by Schaal[6], who, for technical purposes, oxidized petroleum with air in presence of alkali, the only statement regarding them being that they resemble the oleic acids.

The inertness toward bromine of the acids of the series $C_nH_{2n-2}O_2$, isomeric with the oleic series, is only explainable on the supposition that here, instead of the "double linkage" of carbon atoms, we have saturated or methylene rings. From this has been concluded that, as the naphthenes are hexamethylene derivatives, so also are the naphthene acids associated with them. This conclusion is not entirely justifiable. It has been definitely proved of but very few of the naphthenes that they are hexamethylene derivatives; it has been proved of none of the naphthene acids, and in no case has a proved hexamethylene hydrocarbon been oxidized to a definite acid or mixture of acids of the naphthene series. It is quite possible that some naphthenes as well as some naphthene acids may be tri-, tetra-, or penta-methylene derivatives. The carbon skeletons:



all give hydrocarbons C_7H_{14} and acids $C_7H_{12}O_2$ which would be inert toward bromine. We know a number of such bodies, and we know nothing to preclude their existence in petroleum. We may, however, include them all in the same general class, *naphthenes*, and with this definition we are justified in inferring the presence of naphthenes in sand-

[1] Ber. deutsch. chem. Gesell., Jahrg. VII, p. 1216; Jahrg. X, p. 451.

[2] Aschan, Ber. deutsch. chem. Gesell., 1890, Jahrg. XXIII, p. 867.

[3] Ibid, p. 875

[4] Markownikoff and Ogloblin, J. d. russ. phys. chem. Gesell., 1883, (1) 237, 307; Ber. deutsch. chem. Gesell, Jahrg. X'I, pp. 1873, 1878.

[5] Krämer and Böttcher, Ber. deutsch. chem. Gesell. 1887, Jahrg. XX, p. 598.

[6] D. R. Pat. 2,705; Ber. deutsch. chem. Gesell., 1885, ref. 18, p. 680.

alina from the presence of naphthene acids among its oxidation products. The small quantity obtained is not surprising, remembering that the acids are attacked by chromic acid even more easily than the hydrocarbons, being burned up to acetic and carbonic acids and water. The amount obtained, about 5 per cent, was only that which had momentarily escaped oxidation by solution in the oil, at the four times when the operation was interrupted. By more frequent extractions with alkali, and perhaps other modifications, it might be possible to get a much larger yield, and sandalina would probably be found to consist mainly of naphthenes. Perhaps similar oxidation experiments, made with pure hydrocarbons isolated from petroleum, and with undoubted hexamethylene derivatives, whose constitution has been proved by synthesis or otherwise, would help to confirm the opinion, now resting on a very slender basis, that all naphthenes and naphthene acids contain saturated six-atom carbon rings.

The composition of sandalina, expressed in a formula, $C_nH_{1\cdot74n}$, indicates a larger amount of carbon than is required by C_nH_{2n}. This may well be caused by saturated ring hydrocarbons bearing the same relation to the naphthenes C_nH_{2n} as diphenyl, naphthalene, etc., have to benzene.

The results obtained may be thus summed up. Sandalina is characterized by its peculiar odor, suggesting cedar wood; by the almost total absence of bodies other than hydrocarbons and by the comparative absence of such of these as boil below 230° and above 330° C., these being 3·3 and 11·3 per cent, respectively.

Paraffin wax is absent, and other paraffins, if present, probably only in subordinate quantity.

Unsaturated fatty hydrocarbons do not amount to more than 1 per cent.

Naphthenes are present in large quantity, and probably make up the bulk of the oil. In this respect it is allied to the Russian petroleums.

Naphthene or petroleum acids are formed and may be separated in notable quantity even in a rapidly conducted oxidation with chromic acid. The final products of oxidation are carbonic acid, acetic acid, with traces of higher homologues, and water. Small quantities of acetone were also obtained.

JULY, 1890.

ON A SUPPOSED MINERAL RESIN FROM LIVINGSTON, MONTANA.[1]

By H. N. Stokes.

In the vicinity of Livingston, Montana, there is found, coming from the cracks of the limestone, in masses up to 12 or 15 pounds, an amber-colored substance of resinous appearance. It consists of irregular fragments, very brittle, and easily powdered. The surface, where not broken, appears as if fused. Many of the pieces have a stalactitic form, sometimes opaque, with concentric rings of lighter and darker substance, sometimes quite transparent, in which case a decided green fluorescence is observable. When cool it is odorless, but on heating it fuses and emits an odor suggesting fresh cherry-tree gum. On further heating, the odor suggests that of burning Indian hemp. The voluminous carbonaceous residue burns away easily, leaving a nearly colorless ash, consisting almost wholly of carbonates. An ash determination gave 10·3 per cent., consisting chiefly of calcium and magnesium carbonates, with some silica, phosphoric acid, ferric oxide, and potassium and sodium carbonates. It is insoluble in alcohol, ether, and other solvents, except water, which dissolves it easily and almost completely; and on adding an acid a resinous precipitate is formed, but much organic matter remains in solution. It obviously consists of salts of the above bases, with organic substances of acid nature, and in part, at least, of vegetable origin.

The organic substance obtained by decomposing it with an acid was partly soluble, partly insoluble in water, but almost entirely in alcohol and ether, and was not acted on by Fehling's solution or phenylhydrazine before or after heating. From this may be inferred the absence of gum and of true carbohydrates.

Eighty grammes of the substance were dissolved in hot water, the solution filtered, and barium acetate solution added until no further precipitate formed. This was washed, heated with dilute hydrochloric acid, and the insoluble residue, after washing with water, alcohol, and ether, dissolved in dilute caustic potash, and the highly diluted solution acidified with sulphuric acid. After some time crystalline plates separated, which were purified by redissolving in alkali and acidifying.

[1] Sent for examination to the Smithsonian Institution by J. C. Vilas, of Livingston.

The yield was about 5 per cent. The substance thus prepared formed colorless, transparent, nearly rectangular plates, with serrated edges, or sometimes crossed prisms. On heating, it decomposed without fusing, giving off white vapors and leaving a porous coal. With sodium and iron solution it gave an intense reaction for nitrogen. The potassium salt was with difficulty soluble in concentrated alkaline solutions, and its solution was precipitated by carbonic acid. On evaporation with concentrated nitric acid it gave a reddish residue, becoming violet with ammonia; on adding caustic potash, this changed to purple. The last, the well known murexid reaction, as well as the other properties, indicated that the substance was no other than *uric acid*. This was confirmed by analysis.

The air-dried substance lost, partly over sulphuric acid, partly at 100°, 11·01 per cent water.

The dried substance gave:

	Found.	Required by $C_5H_4N_4O_3$
C.....	35·84	35·67
H.....	2·54	2·38
N.....	33·39	33·40

Pure uric acid, dissolved in alkali, diluted largely and acidified, gave crystals of exactly the same appearance as those of the substance in question.

It may be well to call attention to the fact that uric acid is always mentioned in the text books as free from crystal water. This is true only under certain conditions. When slowly separated from dilute solution it may contain it. The water found alone corresponds approximately to 1 mol. H_2O (calculated 9.68 per cent). In an apparently forgotten observation of Fritzsche [1], 2 mol. H_2O were found.

The filtrate from the barium urate precipitate was precipitated by an excess of lead acetate, and the filtrate from this again precipitated by basic lead acetate. The two precipitates thus obtained showed such similar properties that they may be considered together. They were decomposed under alcohol by hydrogen sulphide, and the alcohol boiled off, with gradual addition of water, which caused the deposition of a resinous substance which became very strongly electric when pulverized. Nitric acid oxidized it with formation of yellow nitro products. The aqueous solution from which this had separated left a vitreous mass on evaporation, which was largely soluble in water. By repeated extractions with hot water this was separated into a part easily soluble and one almost insoluble in water, but both soluble in alcohol and ether, and forming amorphous brownish masses. The substance soluble in water gave oxalic acid when oxidized by nitric acid. Analyses failed

[1] Liebig's Annalen, vol. 32, p. 315.

to throw any light on the nature of these substances. The easily soluble substance contained:

C	56·88
H	6·39
N	2·88

It seems that these bodies, which make up the bulk of the substance in question, belong to the class of humus substances of which so little is understood and the properties of which rendered it useless to attempt anything further with these. The substances, fused with caustic potash, gave a solution which, after acidifying, was turned green by ferric chloride and red by subsequent addition of alkali, a reaction characteristic of protocatechuic acid, a usual product of the action of fusing potash on humus bodies.

The filtrate from the lead acetate precipitates, after throwing down the excess of lead with sulphuric acid, was many times shaken out with ether. The ether left, on evaporation, a transparent gummy mass, in which, after some time, well defined crystals appeared. On treatment with chloroform the amorphous substance dissolved, and the residual crystals were several times recrystallized from water with aid of animal charcoal. The substance, of which only a few decigrammes were obtained, formed fine white needles, and was strongly nitrogenous. Having found uric acid, this body at once suggested *hippuric acid*. That it was this is shown by comparison of the two:

Body in question.	*Hippuric acid.*
Needles, fusing at 187°; soluble with difficulty in cold water; soluble in alcohol; insoluble in chloroform.	Needles, fusing at 187.5°; soluble with difficulty in cold water; soluble in alcohol; insoluble in chloroform.
Decomposed by strong hydrochloric acid, giving benzoic acid; recognized by its fusing point, 121°, and other properties, and an easily soluble sweet body.	Decomposed by strong hydrochloric acid into benzoic acid and glycocoll.

The remaining substance, less than 0.07 gramme, gave the following result on combustion:

	Found.	Required for $C_9H_9NO_4$.
C	61.73	60.33
H	5.88	5.0

The agreement is as close as could be expected with the small amount available for analysis.

The occurrence of two such characteristically animal products as uric and hippuric acids, together with substances of vegetable origin combined with lime and magnesia and forming stalactitic exudations from limestone, is easily explained. The mixed products of animal and vegetable life of acid nature soaking through the rock have combined with lime and magnesia, forming easily soluble salts which have been left on emerging by the evaporation of the water, forming this clear, amber-like substance, which shows no outward evidence of its connection with excremental materials.

JULY, 1890.

PRELIMINARY NOTE ON THE COEFFICIENTS OF THERMAL EXPANSION OF CERTAIN ROCKS.

By William Hallock.

The object of the present paper is to give only an outline of the aim and progress of the investigation which is being carried on in the physical laboratory of the U. S. Geological Survey for the purpose of collecting data as to the thermal expansion of all such rocks as may be interesting from a scientific or an economic point of view. Such an undertaking may never be called finished, and for this reason a report from time to time may be desirable.

It is hoped that the present investigation may be made more complete than previous ones by the addition of the complete chemical and microscopic petrographic analyses of each stone examined, such analyses being made by the corresponding branches of the Survey.

As regards the purely physical portion of the work the point of prime importance is the determination of the mean coefficient of expansion for ordinary ranges of temperature. Of minor, but sufficient, interest is the examination of any peculiarities, such as expansion differing in different directions coordinate to the bedding or cleavage planes of the rocks; behavior dry, saturated with water, and in their natural state, and perhaps other questions.

METHODS.

The imagined difficulty of obtaining bars of stone long enough and of sufficiently small cross section for convenient examination, combined with the existence in the National Museum of hundreds of cubes of various stones which seemed available for a determination of the coefficient of cubical expansion, and the apparent simplicity and compactness of the latter method, led to the attempt to obtain at least preliminary values of the mean coefficient by the displacement or pycnometer method.

With a view to using the 4-inch cubes collected by the Tenth Census and stored in the National Museum a cubical cast-iron box was constructed of a similar design to the cylindrical one soon to be described. Owing to the sharp corners and imperfect fit of the cover it was practi-

cally impossible to get this box air tight and perfectly filled with mercury. This fact, combined with the experience that the cubes would necessarily be more or less defaced and rendered unsuitable for exhibition, led to the abandoning of the cubical and the adoption of the cylindrical form, preparing our own samples from selected sources.

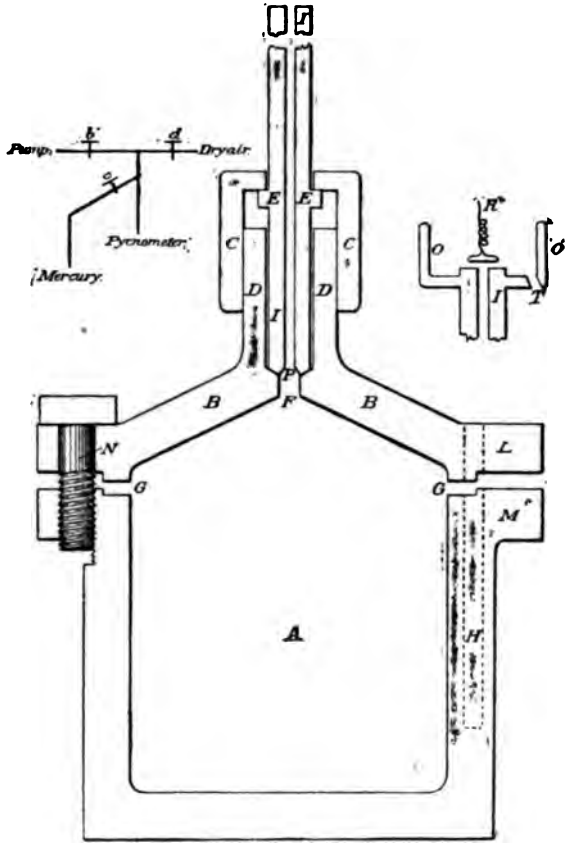


FIG. 4.—Pycnometer.

A vertical section of this design of pycnometer is given in Fig. 4. A[1] is a cylindrical box 3·2 inches in diameter and 3·2 inches high inside measurement. The walls are 0.5 inch thick and are constructed with a broad flange M and shoulder G at the top. The cover B having a corresponding flange L and shoulder G, is held to the box by six bolts, as shown at N. The opening in the tubulure D contracts by a conical seat P to the passage F. A cap C screws down over D, catching the flange E, and holding the tube I firmly into its conical seat at P. The lower end of I and its seat in B at P, are ground to a fit, as are also the cover and box on the shoulder G. A hole H runs down into the wall

[1] This box was very nicely made by the American Tool and Machine Company, of Boston, Massachusetts.

of the pycnometer, and in it is placed the thermometer, surrounded by mercury. This whole vessel is in turn shut up in a second iron box, where it can be maintained at certain constant temperatures by surrounding it with vapors, as ether, methyl and ethyl alcohol, water, etc., with suitable appliances for establishing a continuous condensation of the vapor after use and returning it to the boiling reservoir. Of course, the thermometer and tube I extend through the lid of the vapor bath, and through the coating of asbestus felt with which it is surrounded.

The method of operating this apparatus is as follows: The cover B is screwed on, the joint at G being treated with a little powdered graphite. The tube I is connected to a sprengel pump by a system of tubes shown in the upper left corner of Fig. 4. The pycnometer is evacuated and filled with dry air several times; then while *a* remains closed it is once more pumped out and the valve *b* closed, whereupon by opening *c* the mercury rushes in and fills the space A completely, as well as the tube I. The whole apparatus is then put into the bath box and the cup O screwed onto the top of I. With a small platinum spoon, mercury is filled into I until it stands convex above the top; it is then "struck" off by pressing the plate R down on top of the tube, the overflow being always caught in the same little flask and weighed. This operation may be repeated as often as desired to obtain check readings at the same temperature, of course, refilling I each time out of the weighing flask. With practice and care such readings in extreme cases need not vary 5 milligrammes. The thermometer in the hole H gives the temperature of the materials. Such readings are made at various temperatures, and from the overflow of mercury, assuming the coefficient of mercury as known, it is possible to calculate the coefficient of iron, since the weight of the mercury gives us its volume. In order to determine the coefficient of any given rock, a sample is prepared, which should, as nearly as possible, fill the pycnometer; it is placed in the box, the cover bolted on, and the unoccupied space filled with mercury as before. The remaining operations are identical with those when the pycnometer contained only mercury. The volume of the mercury surrounding the stone, is deduced from its weight, and subtracted from the volume of the pycnometer, gives the volume of the stone. Then knowing the coefficient of the mercury and iron, and the volumes of the stone, iron, and mercury, and the apparent coefficient of the stone and mercury in the iron, a simple calculation gives the coefficient of expansion of the stone alone. The linear coefficient is practically one-third the cubical.

In order to test the speed with which the temperature penetrated such a block of stone, and the justice of assuming that a thermometer in H gave with sufficient accuracy the temperature of the stone, the following experiments were made: A block of marble[1] cut to fit the pycnometer was bored axially to receive a fire-clay tube, with two small bores

carrying one joint of a thermo-element whose other joint was tied to the thermometer bulb in the mercury in H. The arrangement of the inner juncture will be understood from Fig. 5. A is the block of stone, B the clay tube, E the wires of the thermo-element, and C their juncture. B is cemented into A, and the space around C is filled with mercury, whose temperature must penetrate from the sides of A. This block was put into the pycnometer and surrounded with mercury, using a special cover in place of B, Fig. 4. Electrical determinations gave at any moment the difference in temperature between the two junctures, i. e., between the thermometer bulb and the center of the marble block. A series of observations was made, heating the vessel as rapidly as possible in a steam bath. From these data it appears that the difference in temperature, at a given instant, inside the marble and on the thermometer never exceeded 10° or 12° C., which of course occurred during the most rapid portion of the rise in temperature. It also appears that during the rapid rise the interior reached a given temperature between 4 and 5 minutes after the thermometer. Of course this period became longer as the difference of temperature became less. These results convinced me that after 30 to 60 minutes the thermometer gave the temperature of the whole stone within the limits of other errors.

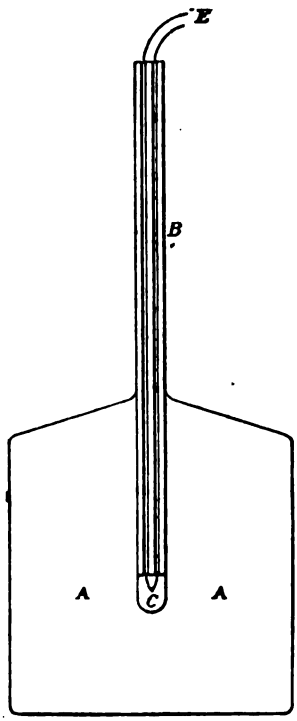


FIG. 5.—Apparatus for measuring penetration of temperature.

This method of obtaining the coefficient of cubical expansion was tried upon a Cockeysville (Maryland) marble,[1] an obsidian from the Yellowstone National Park, and a Berea (Ohio) sandstone. The mercury penetrated the porous sandstone to such an extent that it was impossible to make any readings. In the case of the marble and obsidian fair values were obtained, but there seemed to be some uncertainty as to their behavior, and even with these stones it seemed almost impossible to completely eliminate air and moisture from the sample, either of which vitiated the results. There seemed also a source of error arising from the differences of "fit" of the mercury to the stone at high and low temperatures. In other words, the mercury when hot seemed to penetrate more perfectly into the angular cavities in the uneven surface of the stone. These objections might be overcome, and I hope at some time fully to investigate them; but they more than coun-

[1] A Cockeysville marble, kindly furnished by Hugh Sisson & Sons, of Baltimore, Md.

terbalanced the expected simplicity and quickness of the method, and led to its temporary abandonment, a step urged, too, by the necessary limitations of the method to the determination of the coefficient of cubical (mean) expansion of especially compact and dry stones.

It was my desire from the first to measure directly the linear coefficient of at least the most interesting specimens, especially sets of three cut in directions coordinate to the bed plane. For this purpose a comparator was purchased of the Société Genévoise, of the usual form made by them, with some slight variations. Fig. 6 may serve as a dia-

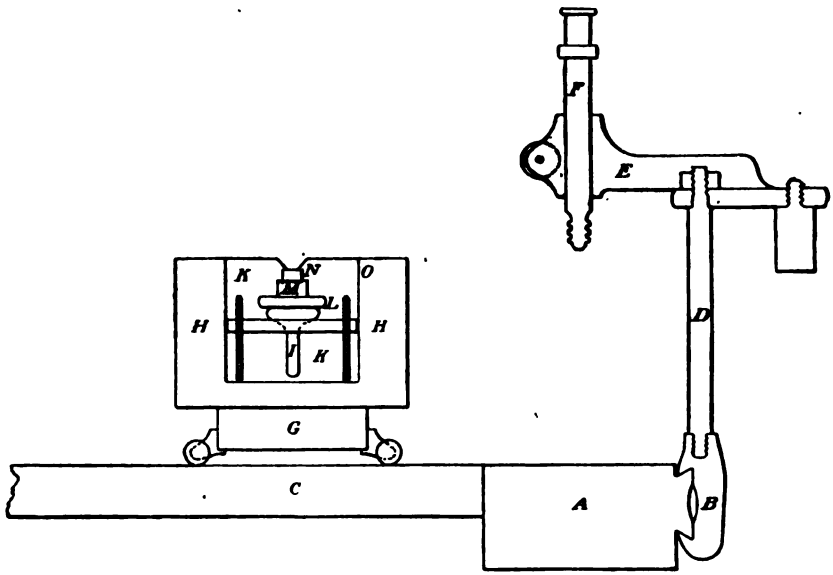


FIG. 6.—Comparator used in determining rock expansions.

gramatic sketch of the comparator and attachments on a vertical section through one microscope. A heavy cast iron base A is furnished with a longitudinal projection on the back which is planed true and carries the sliding clamps B. Two upright posts D carry the counterpoise and arm E through which runs the microscope F. Parts of the bed plate A are cut transversely, forming a track for the car G; these tracks I extended by bolting on bars C so that the car could be removed at least one and a half feet from the bed A. Suitable guides and stops insured the return of the car to its proper place under the microscopes. This car G carried the bath KK surrounded by the box and asbestus felt H. The bar to be measured M rests on rollers L on a T bar I which is furnished with screws for the various necessary adjustments. N is a block of plate glass lying on the divisions and extending above the surface of the water, thus always allowing a reading without readjustment of the microscope and undisturbed by dirty water. Each of the microscopes is furnished with Ramsden micrometer ocular and 2-inch

objective. The car and bath are allowed to stand over the bed plate only long enough for a series of readings and then removed and a screen put up between them so the temperature of the bed remains independent of the temperature in the bath K.

The ocular micrometer screws are four threads to the millimeter, and the head is divided to fifty parts. The enlargement of the objectives is about three times, hence a whole division on the head $=\frac{1}{50}\times\frac{1}{4}\times\frac{1}{3}=\frac{1}{600}$ mm on the bar, hence a theoretical accuracy of $\frac{1}{1000}$ is readily obtainable. Two thermometers bedded in mercury and covered with asbestus, one on the bed over A, the other against the back in the hollow opposite B, served to give the temperature of the comparator which always remained nearly constant at room temperature. Two other thermometers gave the temperature of the bath KK. These thermometers were divided to $\frac{1}{5}$° C., giving thus about $\frac{1}{20}$° to $\frac{1}{40}$° C. The extremes of temperature were about 20° and 100° C, thus the relative accuracy was about $\frac{1}{30}\times\frac{1}{80}$ or $\frac{1}{2400}$ or 0.04 per cent as regards temperature. A brass bar expands for 80° C. about 1.3 mm; this measured with the micrometer accuracy of $\frac{1}{1000}$ mm gives a relative accuracy of 0.08 per cent as regards length. Roughly, then, the theoretical limit of relative accuracy is not far from 0.1 per cent. Of course it would be less if the bar expanded less.

With this apparatus the coefficient of a standard brass bar was determined, as well as that of the iron bedplate, and of a standard meter belonging to the Physical Laboratory. It is intended to check many of the relative determinations by this absolute method, especially where any peculiar behavior occurs in a sample, or any one to which particular interest attaches.

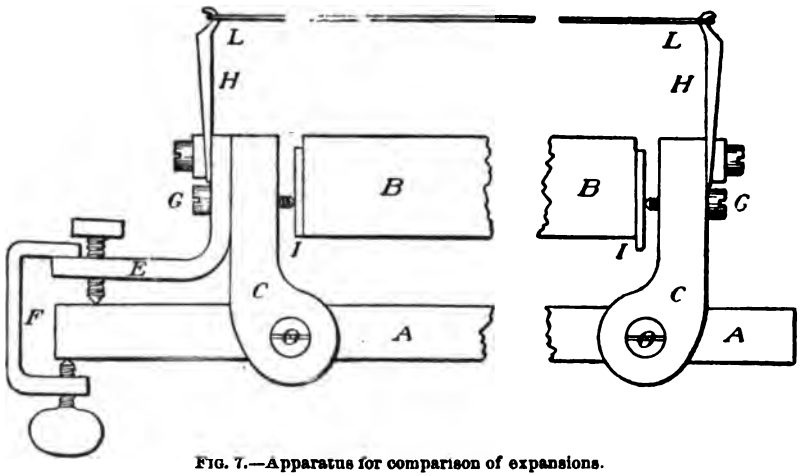


FIG. 7.—Apparatus for comparison of expansions.

In most cases a relative method will be employed and the rocks compared with the standard brass bar above mentioned. Fig. 7 is a plan of the apparatus for these relative determinations. A is the standard

brass bar 110 centimetres long, and 1.4 centimetres square; B is the bar of stone 92 centimetres long and about 3 centimetres square; D is the stationary arm or lever held in place by the foot and adjusting screw E, and clamp F. The screw G, through D, ends in a blunt point, against which rests the glass plate I and the bar B. The method of fastening the levers D and C to the bar A is shown in Fig. 8. In the lever C the screw G is the counterpart of that in D. The extensions HH of C and D carry the wire L which is furnished with a spiral spring in the center, serving to hold the lever C snug against the glass and bar, and these in turn against the glass and screw in D. Thus, as the two bars expand or contract, the lever C, rotating around the center of the screw O, follows the relative changes of length. In Fig. 8 the parts are lettered as in Fig. 7. The screw O has a 60° point, N, as also the upright, T; these fit into center-punch marks on the bar A, so that when T is screwed down snug and clamped with the nut P, the lever is firmly held and yet free to rotate around the axis of T and O. The upper end of T carries a head R, which holds the mirror M. The clamp nut P allows the head to be fastened in any azimuth on T and the screws and spring Q allow slight adjustments of the mirror. The whole combination is hung in a water bath, one end of A being rigidly clamped, and its remaining parts rest on rollers. The stone bar is swung on spiral springs between the screws G, and has perfect freedom of motion. The upper part of T projects above the bath and allows the reading of the rotation of the mirror in the usual method with telescope and scale. The lever D carries a similar upright with head and mirror which furnishes the correction in case the whole system has moved. The long copper water bath is heated by a burner under its whole length and is protected on its sides with asbestos felt. When the bars are in place, the bath is covered with sheet lead and many layers of woolen blanket, nothing appearing above the blanket but the two mirrors and two thermometers. Appropriate inlet and outlet and gauge enable the apparatus to be run for many hours at any given temperature, nearly constant.

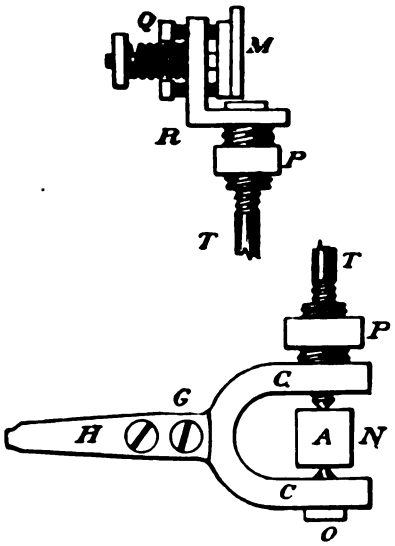


FIG. 8.—Portion of preceding apparatus.

MATERIALS.

In order to test the apparatus and determine its capabilities, as well as in view of their possible economic interest, several samples of com-

mercial stones were investigated. They also possessed the advantage of being easily obtained in convenient shape. The local dealers, however, could not furnish samples three feet long and one inch thick, less than three or four inches wide. Consequently I rigged a saw in the laboratory shop and each such piece was cut into three available pieces, three feet long and a little over one square inch section.

In this way the following samples[1] were cut out and determined:

I. A slate from the Lake Shore quarry near Hydeville, Vermont. It is compact and fine, of a purplish color slightly mottled with green. Sample is cut parallel to the cleavage.

II. A marble from Rutland, Vermont, fine grained, apparently cut parallel to bedding plane and striated with seemingly thin strata of alternatingly light and dark material.

III. A marble from Knoxville, Tennessee, rather fine grained, pinkish marble of the "Tennessee" type.

IV. A marble, "Keowa," from the Happy Valley quarry, Georgia, medium grained, pinkish, mottled, and containing numerous masses rich in mica, *very* lacking in homogeneity.

V. A marble, "Creole," from the Happy valley Quarry, Georgia, coarse, even grained, largely mottled with blackish masses.

VI. A marble, "Cherokee," from the Happy Valley quarry, Georgia, very coarse, even-grained, nearly pure white.

As soon as possible oriented sections will be cut from these bars, and ground and microscopically examined.

The following analyses were made in the chemical laboratory of the Survey by Mr. L. G. Eakins.

The Roman numerals heading the vertical columns designate the corresponding sample above described.

	I.	II.	III.	IV.	V.	VI.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	58·15	.....	·17	2·23	.....	.....
TiO_2	·93	.....	.....	.....	.....	.....
Al_2O_3	18·93	·39	·04	·91	·17	·15
Fe_2O_3	2·91	.....	·23	·22	.....	.....
FeO	5·64	·14	.....	.....	·05	·06
MnO	·07	.....	.....	.....	.....	.....
CaO	·60	50·79	55·47	52·16	53·91	53·69
MgO	2·70	trace	·30	2·09	·83	·83
K_2O	3.92	.....	.....	.....	.....	.....
Na_2O	1·17	.....	.....	.....	.....	.....
H_2O	4·56	1·01	·21	·45	·13	·17
P_2O_5	·12	.....	.....	.....	.....	.....
SO_3	·16	.....	.....	.....	.....	.....
CO_2	.....	39·20	43·63	42·22	43·16	43·13
Insoluble	.....	8·00	.....	.....	1·84	2·01
	99·86	100·13	100·05	100·28	100·09	100·04

[1] All the samples were furnished by J. F. Manning, Washington, D. C.

Analyses of insoluble parts of II, V, and VI.

SiO_2		56·69			58·21	55·48
Al_2O_3		31 16			7·37	15·58
FeO		2·13			·31	trace
CaO		2·68			12·53	14·52
MgO		3·27			20·42	12·88
	Alkalies present undetermined.					
		95·93			98·84	98·46

The coefficients of linear thermal expansion of these samples is given below:

Standard brass bar	0·00001866
I	0088
II	00659
	*00661
III	00495
	00525
IV	00348
	00309
V	0110
VI	00740
	00786
	00855

From an examination of the above duplicate determinations it will be seen that, owing to the small coefficient of the stone compared with the brass, the absolute errors make a considerable relative error in the coefficients of some of the stones. In future better results are expected from the improved state of the apparatus, and also from absolute determinations by the comparator above described.

A peculiar phenomenon was developed in the later determinations on marbles, notably the Vermont and Knoxville samples. Being heated for the first time to 100° C. and allowed to cool, they did not contract to their original length, and the next two or three heatings resulted in continued but ever diminishing increments of length at ordinary temperatures; finally a permanent condition was reached, but not until the bar was 0·2 to 0·3mm longer at ordinary temperatures than originally. The length at 100° C. was practically constant from the first. These observations will be further tested and repeated in subsequent investigations.

A series of observations was made to determine the relative length of a bar in its natural condition, dry and saturated. The Vermont second sample was used. The bar had been lying twenty days in the laboratory when it was placed in the copper bath, which had been emptied and carefully dried. The length of the bar was accurately determined in this condition. Dishes containing concentrated sulphuric acid were next introduced, and the bath covered with glass and paraffine paper

* The duplicate values are always from different bars of the same stone.

and sealed tight with paraffine. In this way the bar was gradually dried in a dry atmosphere. After several days the acid was removed and the bath filled with water. The accompanying curve shows the

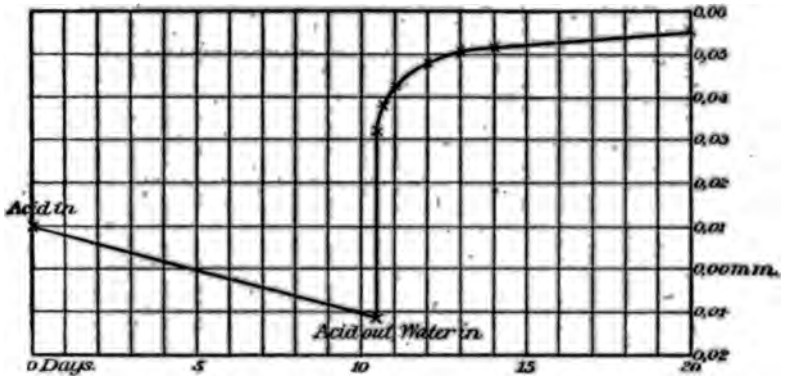


FIG. 3.—Diagram showing expansion of a bar of marble on wetting.

lengths reduced to the same temperature. From the curve it will be seen that the marble contracted on drying, and expanded on soaking full of water, the elongation amounting to about 0.0001.

So many questions still need investigating and so many points must still be considered as not sufficiently established, that it seems best to leave all discussions and speculations until more abundant and better data are available.

MISCELLANEOUS ANALYSES.

ASTROPHYLLITE.

From El Paso County, Colorado.

[Analysis by L. G. Eakins.]

SiO_2	35·23
TiO_2	11·40
ZrO_2	1·21
Ta_2O_5	·34
Fe_2O_3	5·61
Al_2O_3	trace.
FeO	27·33
MnO	5·52
CaO	·22
MgO	·13
K_2O	5·42
Na_2O	3.63
H_2O	4·18
	100·22

BROWN HORNBLENDE.

From Pierrepont, New York. Specimen collected by G. H. Williams.

[Analysis by T. M. Chatard.]

H_2O at 110°	·05
H_2O at red heat	2·41
SiO_2	56·44
TiO_2	·11
P_2O_5	trace.
Al_2O_3	1·77
Fe_2O_3	·84
FeO	·73
MnO	·11
CaO	11·83
MgO	22·98
Na_2O	2·13
K_2O	·75
	100·15

KYANITE.

A pale green variety, intimately associated with the dumortierite from Clip, Arizona.

[Analyzed and collected by W. F. Hillebrand. Sp. gr., 3·656, 18°.5.]

SiO_2	36·30
TiO_2	
Al_2O_3	63·51
Fe_2O_3	·70
FeO	undet.
CuO	trace.
F	none.
B_2O_3	none.
Ign.	·40
	39·91

Titanic acid is present in appreciable amounts, but was not separated from alumina. The mineral contained a few black, non-magnetic grains which may have carried the titanium.

LIEBENERITE?

A massive white mineral from the Brown tin mine, Rapid City, South Dakota.

[Analyzed by W. F. Hillebrand and E. L. Howard. Lime and magnesia not looked for.]

SiO_2	43·62
Al_2O_3	40·38
MnO	trace.
K_2O	10·20
Na_2O	1·12
H_2O	4·94
	100·35

KAOLIN.

A. From Garland County, Arkansas, 14 miles from Hot Springs.

B. From Greenville, Alabama. Contains fragments of quartz, feldspar, and mica.

C. From Georgia side of Savannah River, near Augusta.

[Analyses A (partial) by L. G. Eakins, B by T. M. Chatard, C by H. N. Stokes.]

	A.	B.	C.
H_2O	15·65	6 78	4·16
SiO_2	46·22	69 84	75·73
Al_2O_3	35·20	19·91	16·49
Fe_2O_3	.....	·90	1·31
MnO	.....	trace	.....
CaO	.....	·07	none
MgO	.....	·28	·61
K_2O	.....	2·14	undet.
Na_2O	.....	·21	undet.
	97·07	100·13	98·30

PICRALLUMOGENE.

An aluminum sulphate, near picrallumogene in composition, from the vicinity of Las Vegas, New Mexico.

[Analysis by W. F. Hillebrand.]

Al_2O_3	9·71
MnO	·06
MgO	6·75
Na_2O	2·09
K_2O	·28
H_2O	43·75
SO_3	37·51
	100·15

BROCHANTITE.

From the United Verde mine, Jerome, Yavapai County, Arizona.

[Collected and analyzed by W. F. Hillebrand.]

CuO	69·45
PbO	·04
CaO	trace
Fe_2O_3	·28
P_2O_5	trace
H_2O	12·05
SO_3	16·75
CO_2	·71
Insoluble	·70
	99·98

KERATOPHYR FROM MARBLEHEAD NECK, MASSACHUSETTS.

[Received from J. E. Wolff, analyzed by T. M. Chatard. A, rock; B, separated feldspar.]

	A.	B.
H_2O at 110°	·91	·04
H_2O at redness	1·28	·37
SiO_2	70·23	65·66
TiO_2?	·03	undet.
P_2O_5	·06	undet.
Al_2O_3	15·09	20·05
Fe_2O_3	1·99	trace
FeO	undet.	trace
MnO	·24	·13
CaO	·33	·67
MgO	·38	·18
K_2O	4·99	6·98
Na_2O	4·06	6·56
	100·42	100·64

WEBSTERITE FROM NORTH CAROLINA AND MARYLAND.

Received from G. H. Williams. A, the rock from Webster, North Carolina, formerly supposed to be saxonite. B, from Hebbville, Maryland. C, bronzite from B. D, diopside from B.

[Analysis A, by E. A. Schneider; B, C, D, by T. M. Chatard.]

	A.	B.	C.	D.
SiO_2	55·14	52·56	54·52	51·69
TiO_2	trace	·14	undet.	·13
P_2O_5	·23	trace	trace	trace
Al_2O_3	·66	2·71	1·93	2·21
Fe_2O_3	3·48	1·27	1·70	1·29
Cr_2O_3	·25	·44	·30	·51
MnO	·03	·24	·28	trace
FeO	4·73	4·99	3·92	3·59
NiO	·11	.....	.....	.....
MgO	28·66	29·29	29·51	17·76
CaO	8·39	10·52	2·25	20·99
K_2O	.....	} ·27	.....	undet.
Na_2O	·29		.....	undet.
H_2O	·28	1·69	1·14	·65
	100·36	100·52	100·56	98·84

FELDSPARS FROM MINNESOTA GABBROS.

Received from C. R. Van Hise. A, from NW. ¼ of SE. ¼ of Sec. 23, T. 62 N., R. 10. B, center of Sec. 25, T. 64 N., R. 8. C, Duluth and Iron Range Railroad.

[Analyses by W. F. Hillebrand.]

	A.	B.	C.
SiO_2	52·50	52·61	53·45
TiO_2	trace	trace	trace
Al_2O_3	30·15	29·80	29·77
Fe_2O_3	·47	·57	·33
FeO	·15	·23	·15
MnO	.....	trace	.....
CaO	12·82	12·25	11·33
MgO	·10	·20	·11
K_2O	·53	·53	·68
Na_2O	3·72	3·80	4·33
Ignition	·25	·29	·23
	100·69	100·28	100·38

ERUPTIVE ROCK FROM MONTANA.

From Bear Creek, Madison County.

[Collected by A. C. Peale, analyzed by T. M. Chatard.]

H_2O at 110°	·84
H_2O at red heat	3·50
SiO_2	49·13
TiO_2	·42
P_2O_5	·38
Al_2O_3	9·05
Cr_2O_3	·39
Fe_2O_3	3·57
FeO	5·05
MnO	·15
NiO	trace
BaO	·05
CaO	5·68
SrO	none
MgO	17·21
K_2O	2·24
Na_2O	2·01
	99·67

ROCKS FROM CALIFORNIA.

Series collected in sandstone dikes of northern California, by J. S. Diller.

A. From sandstone vein on Salt Creek.
B. Middle Fork of Cottonwood.
C. Vein 1¼ miles below Ono Bridge.
D. 1½ miles up Byron Creek.
E. From Ono.

[Analyses by T. M. Chatard.]

	A.	B.	C.	D.	E.
H_2O at 110°	·78	1·13	·46	·64	·55
H_2O red heat	1·78	2·99	3·27	2·83	
CO_2	12·73	4.97	10·36	·72	.....
SiO_2	48·13	55·85	48·10	67·62	68·10
TiO_2	·24	·76	·47	·48	·35
P_2O_5	·14	·18	·13	·08	·18
Al_2O_3	11·19	13·20	12·16	13·63	15·18
Fe_2O_3	1·25	2·56	1·02	1·25	1·34
FeO	1·47	4·77	2·14	3·27	1·70
MnO	·29	·24	·26	·15	·20
CaO	16·39	6·93	15·88	2·80	4·66
BaO	·04	undet.	undet.	·03	·06
MgO	2·22	1·90	1·65	2·34	2·06
K_2O	1·17	1·89	1·56	1·11	1·48
Na_2O	2·29	2·60	2·46	2·78	3·71
	100·11	99·97	99·92	99·73	99·67

Series from Mount Diablo.

A. Red shale.

B. Jasper.

C. Brown shale.

D. Bastite.

E. Gabbro.

[Analyses by W. H. Melville.]

	A.	B.	C.	D.	E.
H_2O at 105°	1·03	·21	8·74	·94	1·20
H_2O ignition	2·93	·72		12·43	1·83
SiO_2	69·26	93·54	45·64	26·57	47·49
P_2O_5	·05		·27		trace
CO_2			4·69		
Cr_2O_3			·12	.33	
Al_2O_3	11·69	2·26	15·42	·95	15·81
Fe_2O_3	6·23	·45	3·40	7·29	1·07
FeO	1·09	·79	3·73	·27	4·50
NiO				·31	·06
MnO	·49	·23	·23	·10	·41
CaO	·38	·09	8·11	·14	15·53
MgO	1·29	·06	4·62	40·27	10·39
Na_2O	3·72	·51	3·13	·31	1·16
K_2O	·73	·37	1·06	trace	trace
	99·59	99·36	99·96	100·01	99·45

SANDSTONE FROM ARIZONA.

A brown building stone from the Arizona Sandstone Company's quarries at Flagstaff.

[Analysis by T. M. Chatard.]

Insoluble in HCl	79·15
Soluble SiO_2	·04
Al_2O_3	1·30
Fe_2O_3	2·45
CaO	7·76
MgO	·23
CO_2	5·77
H_2O at 110°	·32
H_2O at red heat	2·94
	99·96

LIMESTONE FROM KANSAS.

A light-brownish, fossiliferous marble from Iola.

[Analysis by H. N. Stokes.]

$CaCO_3$	97·94
$MgCO_3$	1·07
Fe_2O_3	·29
Sand and clay	·86
H_2O	·04
	100·20

FIVE CHEROKEE LIMESTONES.

Collected by W. P. Jenney in the lead-zinc region of southwest Missouri and vicinity.

A and B. Quarries near Seneca, Newton County, Missouri.

C and D. From near Grand Falls, Newton County, Missouri.

E. Quarry on Short Creek, near Spring River, Cherokee County, Kansas.

[Analyses by L. G. Eakins, the carbonic acid being found by calculation from the bases.]

	A.	B.	C.	D.	E.
CaO	55·20	54·02	54·98	55·11	55·25
MgO	·23	·20	·31	·32	·35
Al_2O_3	·11	·13	·08	·13	·17
FeO	·05	·07	·05	trace	·20
MnO	trace	trace	·03	trace	·02
Insoluble	·66	1·21	1·01	1·01	·32
CO_2	43·69	43·31	43·54	43·65	43·79
	100·03	99·84	100·00	99·23	100·10

ORES OF IRON.

Series from Virginia, in or near Craig County.

A. McCortney opening, Mill Creek, between Little Mountain and Bailey's Mountain.

B. Red slate ore, top of Bailey's Mountain.

C. Robinson mine, 600 feet above valley, near Houston Station, Shenandoah Valley Railroad.

D. Grace Furnace mine.

[Analyses by L. G. Eakins.]

	A.	B.	C.	D.
Fe	45·01	33·31	49·52	54·45
Mn	1·17	·77	·36	·16
P	·39	·036	·34	·15
S	·21	·18	·14	.28
H_2O	11·54	8·83	10·33	11·19
Insoluble	18·01	37·96	13·39	7·18

Series from North and South Carolina.
A. From Troy, North Carolina.
B. Marietta, South Carolina.
C. Abbeville County, South Carolina.

[Analyses by L. G. Eakins.]

	A.	B.	C.
Fe	49·96	48·44	52·96
Mn	·92	.....	none
P	·04	·07	·94
S	·04	·03	·05
H_2O	15·25	.....	.....
Insoluble	7·10	9·32	4·62

Series from Georgia and Alabama.
A and B. From Bartow County, Georgia.
C, D, and E. Round Mountain, Alabama.
C. "Red Bank."
D. "Ford Tunnel."
E. "Furnace Tunnel."

[Analyses by L. G. Eakins.]

	A.	B.	C.	D.	E.
Fe	65·73	56·24	58·34	55·13	58·56
Mn	none	none	·10	·16	none
P	·03	·13	·209	·731	·212
S	.....	·14	·043	·108	·079
H_2O	·19	12·90	.....	.....	.....
Insoluble	4·63	3·28	9·73	11·26	9·59

Ore from Kentucky. Entry No. 3, Thacker Ridge, near Fitchburg, Estill County:

[Analysis by L. G. Eakins.]

SiO_2	9·41	
Al_2O_3	6·45	
Fe_2O_3	64·79 =	45·35 Fe.
MnO	1·98 =	1·53 Mn.
CaO	3·15	
MgO	·46	
H_2O	11·70	
P_2O_5	2·00 =	0·87 P.
SO_3	·16 =	·06 S.
As	none	
Ti	none	
	100·10	

From Kettle Island, branch of Straight Creek, six miles above Pineville, Bell County, Kentucky:

[Analysis by E. A. Schneider.]

Fe	46·46
Mn	·47
P	1·02
S	·62
Insoluble	4·37

Ores from Tennessee. Samples from Balsam Hollow, three miles west of Cumberland Gap, Claiborne County:

[Analyses by E. A. Schneider.]

	Top.	Middle.	Bottom.
Fe	53·00	35·50	34·60
Mn	·19	·55	·21
P	·24	·23	·40
S	none	·14	·13
Insoluble	21·26	41·53	10·64

Hematite nodule. From near Coyote, Mora County, New Mexico:

[Analysis by E. L. Howard.]

Fe	65·22
P	trace
S	·10
SiO_2	2·51

ORES OF MANGANESE.

From Virginia.

A. Round Head tract, near Marksville, Page County.

B. Trotter property, southeastern part of Augusta County.

[Analysis A by E. A. Schneider, B by L. G. Eakins.]

	A.	B.
Mn	51·46	14·38
Fe	2·94	6·87
Co	.....	·10
P	·23	·760
S	.....	·077
SiO_2	4·17	*62·53
H_2O	4·97	.....

*Insoluble matter.

From Kentucky. Top of Cumberland Mountain, at Lewis Gap, three miles east of Cumberland Gap, Bell County:

[Analysis by E. A. Schneider.]

Mn	59·67
Fe	1·13
P	·24
S	none
Insoluble	1·63

From Tennessee.
A, 7 miles south of Johnson City.
B, small ridge near Johnson City.

[Analyses by L. G. Eakins.]

	A.	B.
Mn	48·51	37·12
Fe	·79	1.67
Cu	trace.	trace.
Co	1·08	1.26
P	·154	·130
S	·066	·088
Insoluble	5·50	20 40

From Bartow County, Georgia.

[Analyses by L. G. Eakins.]

Mn	44·81
Fe	9·51
Co	·35
P	·196
S	·080
Insoluble	1·85

TWO COALS FROM WEST VIRGINIA.

Near railroad from Grafton to Philippi, in Barbour County.

[Analyses by L. G. Eakins.]

	Top.	Bottom.
Fixed C	61·07	59·06
Volatile matter	32·23	33·96
Moisture	1·14	1·10
Ash	5·56	5·88
	100·00	100.00
Ash	White.	White.
Coke	Friable.	Friable.

WATER FROM WEBSTER GROVE, MISSOURI.

A spring 10 miles due west from the center of St. Louis.

[Analysis by W. F. Hillebrand and E. S. Howard. Stated in parts per million.]

SiO_2	26·4
$Al_2O_3 + Fe_2O_3$	2·6
Ca O	135·6
Mg O	21·2
Na_2O	20·2
K_2O	1·5
SO_3	15·4
Cl.	11·0
N_2O_5	15·3
Combined CO_2	104·5
	353·7
Less O=Cl	2·5
	351·2
Total CO_2	109·5
Albumenoid NH_3	·01
Free NH_3	·08

BRASS.

Used in standards of the United States Bureau of Weights and Measures.

[Analysis by W. F. Hillebrand. The estimations of Pb, Bi, and As are approximations only.]

Cu	76·50
Zn	21·99
Pb	·58
Bi	·26
As	·12
Fe	·18
Sn	trace?
	99·63

INDEX.

	Page.
Astrophyllite	119
Bohemian uraninite	72–73
Branchville, Connecticut, analyses of uraninite from	64
Brass, analysis	129
Brochantite	120
Brögger, W. C., furnishes for analyses specimens of bröggerite and uraninite	44, 68, 69
Bröggerite	68, 71
Brucite	32–33
Brush, ——, acknowledgments to	43
Chatard, Thomas M., paper on apparatus for determination of water in mineral, analyses	84–86
paper on seperation of titanium, chromium, aluminum, iron, barium, and phosphoric acid in rock analyses	87–90
Chili, analyses of meteorites from	95, 97
Chlorites	19–24
Chondrodite	95–97
Chrysotile	15
Clarke, F. W., papers by	34–42
Clarke, F. W., and E. A. Schneider, paper on constitution of the natural silicates, by	11–33
Cleveite	72
Coals, analyses	128
Colorado, analysis of uraninite from	65
Cuba, petroleum from	98–103
Dana, ——, acknowledgments to	43
Eakins, L. G., analyses of meteorites by	91–97
Earth's crust, composition of	35, 36–42
Feldspars	122
Glastonbury, Connecticut, analysis of uraninite from	43–44, 48, 49, 50, 52, 53, 62, 74, 75
Hallock, William, acknowledgments to	55
paper on coefficients of thermal expansion of certain rocks	109–118
Hillebrand, W. F., paper on occurrence of nitrogen in uraninite	43–79
Hornblende	119
Iowa, analysis of meteorite from	95–97
Iron ores, analyses	125–127
Jefferisite	28–31
Kansas, analysis of meteorite from	94
Kaolin	120
Keratophyr	121
Kerrite	28–31
Kyanite	120
Leuchtenbergite	20, 21, 22
Liebenerite	120
Lindgren, Waldemar, microscopic examinations of phlogophite by	24–25
acknowledgments to	83
Manganese ores, analyses	127–128
Marble, analyses of	116
Melville, W. H., paper on metacinnabarite from New Almaden, California	80–83
Metacinnabarite from New Almaden, California	80–83
Meteorites, analyses of	91–97
Micas	24
Nitrogen in uraninite	43–79
Nitrogen, apparatus for collecting	56–60
Nivenite	72
Nordenskiöld, A. E., furnishes specimens of uraninite for analysis	44, 68, 69
North Carolina, analysis of uraninite from	65
analyses of meteoric iron from	93–94
Norway, analysis of uraninite from	67
Ocean, chemical composition of	35
Olivine	13
Pallasite	94
Petroleum from Cuba, paper on	98–103
Phlogopite	24–26, 27
Picrallumogene	121
Picrolite	15
Prochlorite	19, 21, 22, 23
Reade, T. Mellard, cited	38
Ripidolite	20, 22
Rock analyses to show composition of earth's crust	36–42
Rock analyses	123, 124, 125
Saxon uraninite	72–73
Schneider, E. A., and F. W. Clarke, paper on constitution of the natural silicates	11–33
Serpentine	15–19
Silicates (natural), experiments upon the constitution of	11–33
Slate, analyses of	116
Stokes, H. N., paper on a petroleum from Cuba	98–103
paper on a supposed mineral resin from Livingston, Montana	105–108
Talc	13–15
Texas, analysis of meteorite from	91–93, 95
Thermal expansion, paper on coefficients of	109–118
Uraninite, occurrence of nitrogen in	43–79
analyses of	60–79
Vermiculites	28–31
Von Leicht, F., acknowledgments to	83
Water from Webster Grove, Maryland, analysis	129
Websterite	122
Woodward, R. S., acknowledgments to	34

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 79

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

DEPARTMENT OF THE INTERIOR

BULLETIN

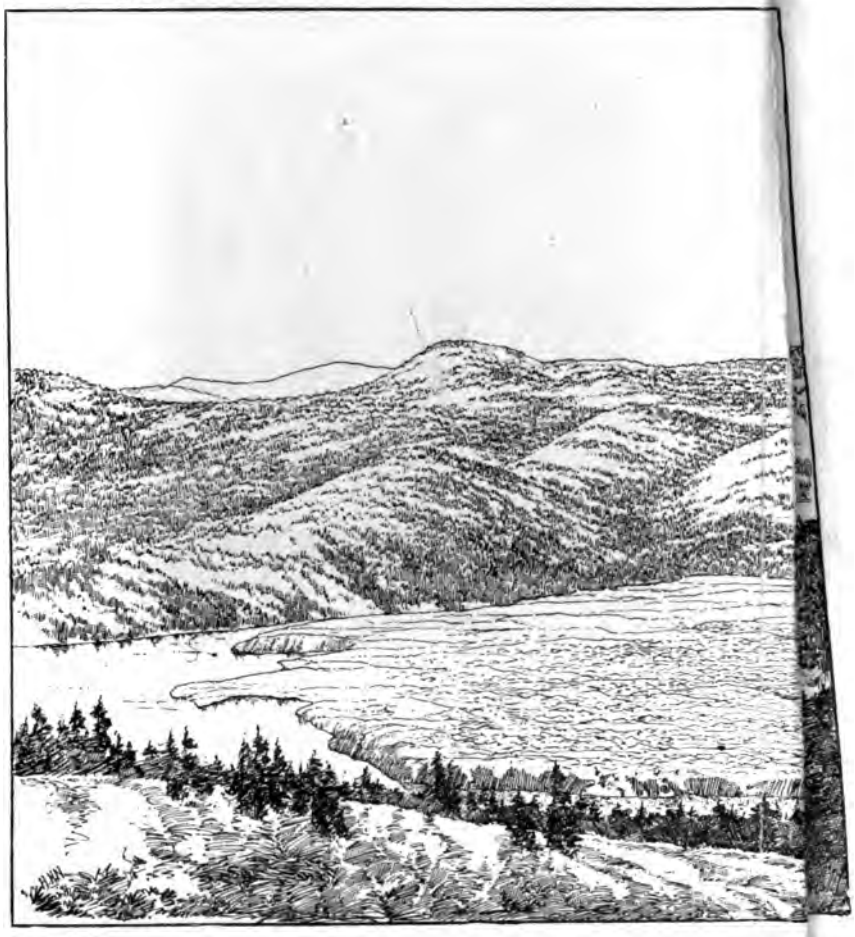
OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 79

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891



UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

A LATE VOLCANIC ERUPTION

IN

NORTHERN CALIFORNIA

AND

ITS PECULIAR LAVA

BY

JOSEPH SILAS DILLER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

CONTENTS.

	Page.
Synopsis of contents	8
Introduction	9
General view of the scene	10
The cinder cone	11
The ash field	13
The lava field	15
Ancient lake bed	17
History of the eruption	18
Age of the eruption	19
The lava-quartz basalt	21
The quartz of the quartz basalt	24
Distribution of quartz basalt	30

ILLUSTRATIONS.

		Page
Plate	I. The cinder cone and lava field from Prospect Peak	Frontispiece.
	II. The lava field and cinder cone, Lassen Peak in the distance	10
	III. The cinder cone, looking north	11
	IV. Volcanic bombs at southwest base of cinder cone	12
	V. The crater of the cinder cone	14
	VI. The edge of the lava field at the northwest corner of Snag Lake	16
	VII. The surface of the lava field, breaking of the lava crust	17
	VIII. The lava field, looking southeast from the cinder cone	18
	IX. The cinder cone, looking west; older and newer lava in the foreground	19
	X. Section through the cinder cone, lava field and Lake Bidwell	20
	XI. Geologic map of the cinder cone region	22
	XII. The lava dam and Snag Lake	24
	XIII. The lava dam and Snag Lake, near view	25
	XIV. Tree pushed over by advancing lava	26
	XV. Older lava, ash field, and Lassen Peak, from the south base of the cinder cone	28
	XVI. Near view of lava	30
	XVII. Sections showing grains of quartz encircled by shells of glass and augite and groups of augite crystals without quartz or glass	32
Fig.	1. Model of lava field and cinder cone, looking northwest across Snag Lake	11
	2. Model of lava field and cinder cone, looking southwest across Lake Bidwell	12
	3. Relations of older and younger forest to volcanic sand	20
	4. Specimens of lava containing quartz, from all parts of the lava field	24

SYNOPSIS OF CONTENTS.

The Lassen Peak, Volcanic Ridge, which connects the northern end of the Sierra Nevada in California with the Coast Range and separates the upper portion of the Sacramento Valley from the great interior basin, is composed chiefly of lavas from many volcanic eruptions. The vents which supplied these lavas may be roughly classified according to size into three groups. They are surmounted by volcanic cones of corresponding dimensions. The smallest cones are the newest, most numerous, and most widely distributed, and to this group belongs the Cinder Cone, 10 miles northeast of Lassen Peak.

It marks the scene of one of the very latest volcanic eruptions in this country. The utter desolation of the place and the apparent newness of the Cinder Cone and the lava and ash field are most surprising.

The Cinder Cone is remarkably regular, smooth, and dark colored. It is composed wholly of ejecta. Rising with steep slopes to a height of 640 feet above its base, it incloses a perfect crater 240 feet deep.

Large volcanic bombs are thickly scattered about the base of the Cinder Cone, from which the ash field extends away in all directions for a distance of about 8 miles. About a quarter of a mile from the cone the layer of volcanic sand is 7 feet thick, and its lower portion is composed of pumiceous fragments. As the distance from the cone increases the sand becomes thinner and finer until it disappears.

The lava field is an extremely rough, tabular pile of large, angular fragments of lava. It terminates upon all sides in a steep, terrace-like edge, averaging about 100 feet in height. A part of the lava is covered with volcanic sand and separated from the newest flow, which forms the greater portion of the field, by about 10 feet of infusorial earth deposited in Lake Bidwell, where it extended farther south than now.

The history of this little volcano embraces two epochs of eruption, strongly contrasted in their phenomena and separated by a considerable interval of repose. The first epoch was characterized by a violent explosive eruption which formed the Cinder Cone and the ash field. Within the latter part of this period of violence some lava was effused, and this was partially covered by succeeding showers of ashes. Then followed the lacustrine period, after which came the quiet effusive eruption of the large mass of rough lava that gave the lava field its present shape and volume.

Judging from the trees which have grown upon the volcanic sand near the Cinder Cone since it was formed, the first and violent eruption probably occurred nearly a hundred years before the American Revolution. The second or effusive eruption took place at a much later date, but certainly more than 50 years ago.

The lava is basalt, one of the commonest kinds of volcanic rock, but it is especially noteworthy on account of the phenocrystic quartz which it contains. The mode of occurrence and distribution of the quartz through the lava demonstrates that it is indigenous to the basalt, and that it was formed at an early stage of its crystallization. This is a characterizing feature of quartz basalt, which is not nearly as rare as was once supposed. Almost thirty occurrences of it are already known.

A LATE VOLCANIC ERUPTION IN NORTHERN CALIFORNIA AND ITS PECULIAR LAVA.

By J. S. DILLER.

INTRODUCTION.

The entire absence of easily recognized volcanic craters in the eastern part of the United States has tended to create the impression that in volcanoes this country is below the average; but to dispel this notion it is necessary only to make a trip through our Northwest. In Washington, Oregon, California, Nevada, and Idaho is the largest volcanic field of the world. It is very true that there are no active craters like Vesuvius, but some of the Western volcanoes have been so recently eruptive that we can scarcely say they are things of the past, and there is abundant evidence to show that their internal fires are still smoldering.

The Lassen Peak district in later geological epochs has been the scene of profound volcanic extravasations, which resulted in its characteristic mountain topography. Lying between the Sacramento Valley on the one hand and the platform of the Great Interior Basin on the other, it joins the northern end of the Sierra Nevada to the irregular mountains of the Klamath province, so intimately related to the Coast Range.

The northern portion of the district is traversed by the Pit River, the modern representative of the ancient water way which, during the closing epoch of the Cretaceous age, lay beneath the sea. Its topographic elements are in general strongly contrasted with those of neighboring districts. The Sierra Nevada and Coast Ranges are elevations formed by uplifting the original surface over large areas, but the Lassen Peak volcanic ridge, which is the most general feature of the district, resulted chiefly from the superficial accumulations of material thrown out from within the earth and piled up in mountain masses about the point of exit. The large vents are represented by

great cones lying in a broad belt, so that their coalescing bases form an irregular ridge culminating in Lassen Peak.

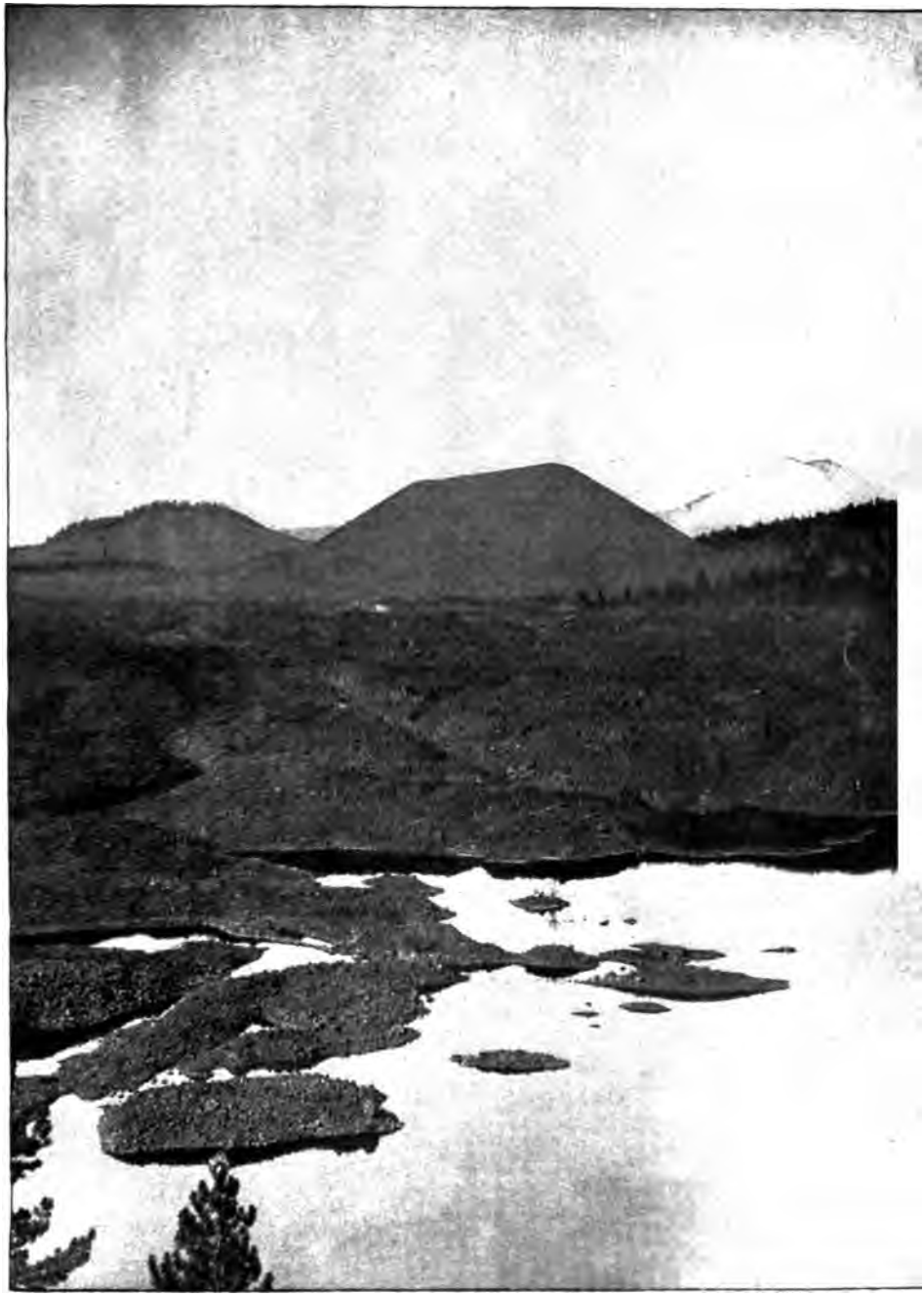
The volcanic cones, of which there are many scores in the district, may be divided according to size into three groups. Those of the first magnitude are four in number, and most ancient; then follow those of the second magnitude, in greater number, of later age, and wider distribution; finally, those of the third magnitude are smallest and most numerous, and have the widest distribution. The last stage of eruptive volcanic action has been manifested in these cones, and to this group belongs the Cinder Cone, 10 miles northeast of Lassen Peak, in the vicinity of Snag Lake.

The material brought to the surface from beneath by volcanic action to build up new topographic features is delivered in two different ways, and both may be in progress at the same time. In the one case the matter, which is wholly fragmental, is violently hurled into the air to be distributed in large part by the winds. In the other case the matter rises to the surface and flows out a continuous body, whose distribution is controlled by the laws of liquids. The ejection gives rise to a cinder cone about the vent, and spreads volcanic sediments far and wide over the adjacent country, covering up the slight irregularities of the original surface so as to produce the flowing contours which characterize ash fields. The effused material forms a lava field, whose features are determined largely by the physical condition of the lava at the time of its eruption.

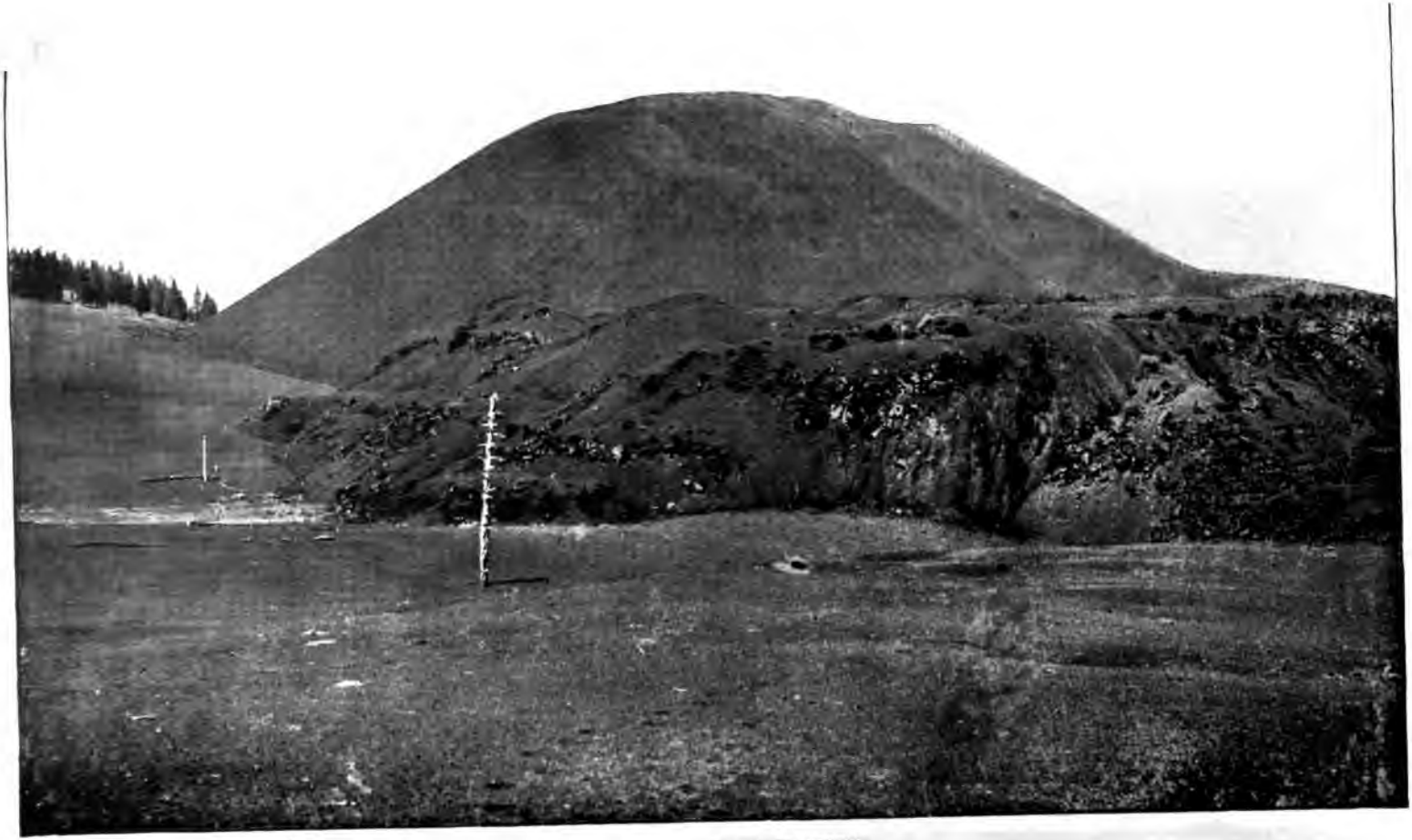
GENERAL VIEW OF THE SCENE.

From the summit of Lassen Peak looking northeast a dark and desolate lava field and crater are pointed out as "The Cinder Cone," and it proves of sufficient interest to receive during the summer the occasional visits of those who are in search of the new and the marvelous. A better example of its kind can not be found anywhere. The nearest stage line ends at Shingletown, Shasta County, nearly 40 miles from the scene of the late eruption. It may be most comfortably reached on horseback by way of Deer Flat and the Hat Creek road, but a camping outfit must be carried along, as there is no settlement near the place. A much more interesting trip to the same place may be made from Plumas County, going by way of Morgan's Springs, Bumpass's Hades, and Lassen Peak and returning through Hot Spring Valley. From the latter locality Tartarus Lake and the geyser near Willow Lake may be easily reached.

Approaching the region the traveler first encounters a sprinkling of fine volcanic sand and small bits of dark brown pumice spread upon the ground. These increase as he goes nearer until the volcanic sand gives character to the whole landscape, imparting a dull, dark hue to the soft earth and rendering travel on foot fatiguing. The best general view of the scene is obtained from the summit of Prospect Peak,



THE LAVA FIELD AND CINDER CONE.



miles northwest of the Cinder Cone, above which it rises over 2,000 et. (Pl. I.)

The lava field lies between Snag Lake on the south and Lake Bidell on the north. Its greatest length is about 3 miles. When the first ar view of the lava field and Cinder Cone is obtained the impression newness is very vivid. One looks in vain for steam rising from the ater and feels disappointed at seeing no visible signs of heat within e thick lava field. Charred tree trunks apparently long ago dead test the scorching temperature of the place in recent times, but one arches in vain on the living trees for bits of volcanic sand from the uption that might have lodged in knot holes or other places suited catch it as it fell.

THE CINDER CONE.

The Cinder Cone is always the principal point of interest on account its novelty as well as its importance and the excellent view it affords the whole scene. From its summit the eye ranges over the lava field retching from Snag Lake to Lake Bidwell, all encircled in the deep een pine forest which covers the gentle slopes of the ash-mantled lls.

FIG. 1.—Model of lava field and cinder cone, looking northwest across Snag Lake.

A fine view of the lava field and Cinder Cone with Lassen Peak in e distance may be obtained on the slope northeast of Lake Bidwell l. II), but a more comprehensive idea of the scene is conveyed by the odel from which Figs. 1 and 2 have been prepared.

The Cinder Cone represented in Pl. III is regular in form with a surisingly smooth dark surface showing no traces of water ways or her marks of the ravages of time. It rises to an elevation of 640 feet ove the lowest point of its base (6,906 feet above the sea) with an erage diameter of 2,000 feet below and 750 feet across the top. Its pes are as steep as it is possible for such loose volcanic material to intain at rest. The angles of the slope range from 30° to 37° accordg to size of the scoria and lapilli. They slide down under one's ight, so as to make the ascent, although but a few hundred feet, a tter of considerable fatigue.

The dull, somber aspect of the smooth, dark slope is greatly relieved by the carmine and orange-colored lapilli upon the southeastern side, so that when viewed from Snag Lake the cone presents the pleasing hues of a sunset. The strangeness of the scene is greatly enhanced by the almost complete absence of vegetation. Only two small bushes cling upon the outer slopes to give life to the barren cone.

FIG. 2.—Model of lava field and cinder cone, looking southwest across Lake Bidwell.

The base of the cone is encircled by a multitude of volcanic bombs as shown in Pl. IV. These were hurled from the crater and, falling upon the steep slopes of the cone, tumbled to its base where they collected in great numbers. Many of the bombs are comparatively small, but a few attain a diameter of 8 feet. They are much jointed, often radially, and are falling to pieces under the influence of the elements. Externally they are cracked like septaria with a more or less ropy or pumiceous surface, often very rough, within they are dark and compact with a low degree of crystallization. Bombs of this sort with some effused lava may form a considerable portion of the lower part of the cone, but its chief mass is of lapilli ranging in size from that of a pea to 4 or 5 inches in diameter.

The summit of the cone is a well developed crater, as represented in Pls. V and X. The pit has a depth of 240 feet, with a narrow bottom and partially slaggy slopes so steep as to be scaled with difficulty. A peculiar feature is the double character of the crater. It has two rims one within the other separated by a shallow moat which encircles the great funnel-shaped depression in the center (Pl. X).

The Cinder Cone marks the position of the vent from which its material was ejected and a large mass of lava was effused. Only the ejected material passed out through the crater, for the pressure of the lava within the cone burst its walls and issued from its southeastern side at

VOLCANIC BOMBS AT SOUTHWEST BASE OF CINDER CONE.

an elevation of about 6,350 feet, forming an excresence which marks the path of easiest ascent. The upper crust of the lava tube which was left empty at the point of egress when the supply of lava ceased has broken in and partly filled with ice, in marked contrast to its igneous condition when the volcano was active.

THE ASH FIELD.

The volcanic sand and fine lapilli thrown out at the time of the eruption spread over a considerable area in all directions from the Cinder Cone.

The southern border of the ash field is seen near Juniper Lake, in the vicinity of Mount Harkness, eight miles from the cone. To the northeast it extends nearly to Poison Lake. In the opposite direction traces of the sand may be recognized in Hat Creek Valley, but it does not extend quite to Lassen Peak. To the north and northwest it reaches far beyond the summit of the prominent mountain at the base of which the Cinder Cone reposes. The outline of the field covered by the volcanic sand is approximately circular, with a radius of nearly eight miles, showing that at the time of the eruption there was no strong wind to modify the regular centrifugal distribution of the sand.

The maximum thickness of the sand at the base of the Cinder Cone could not be definitely ascertained. It is loose and flows easily so that a great deal of excavating is required to get through it where the layer has considerable magnitude, and the bottom was not reached by us at any point within a quarter of a mile of the base of the cone. It is evident, however, that its thickness rapidly diminishes in all directions.

The following table shows the thickness of the sand at various distances from the cone:

Thickness of fragmental material.

Direction from cone.	Distance from cone.	Thickness of sand.	Thickness of pumiceous fragments.	Total thickness.
	Miles.	*Inches.*	*Inches.*	
NE., N., and SW.	¼	52	30	82
N.	½	.....	.....	36
N.	¾	27	8	35
SW.	1	14	10	24
E.	1	10	10	20
SW.	1¼	12	6	18
E.	1¼	10½	5½	16
N.	1¼	.....	.....	15
SE.	1¼	8	4	12
SE.	1½	5½	4½	10
W.	1¾	.....	.....	6
W.	2	2½	2½	5
SW.	2¼	.....	.....	4½

The sheet of fragmental material consists of two portions. The upper part is properly called volcanic sand; the lower part, however, is composed of small, light brown pumiceous fragments ranging in size from that of a pea to an inch in diameter. The fragments are very vesicular but still not sufficiently light to float on water like ordinary pumice. They are very rough and jagged with surfaces torn by the bursting cells once filled with eruptive gases. Some of them were produced by concussion. The pieces hurled violently into the air frequently struck others and all were partially pulverized as in a great mill. This sort of sediment is more abundant in the volcanic sand which overlies the pumiceous material and was therefore ejected at a subsequent stage of the eruption. Many of the sand grains are vesicular, but less so than the pumiceous fragments, and generally rounded. Other grains are angular and composed of compact lava with few vesiculæ. They are bounded by fracture surfaces, and were evidently produced by the violent concussion of larger fragments.

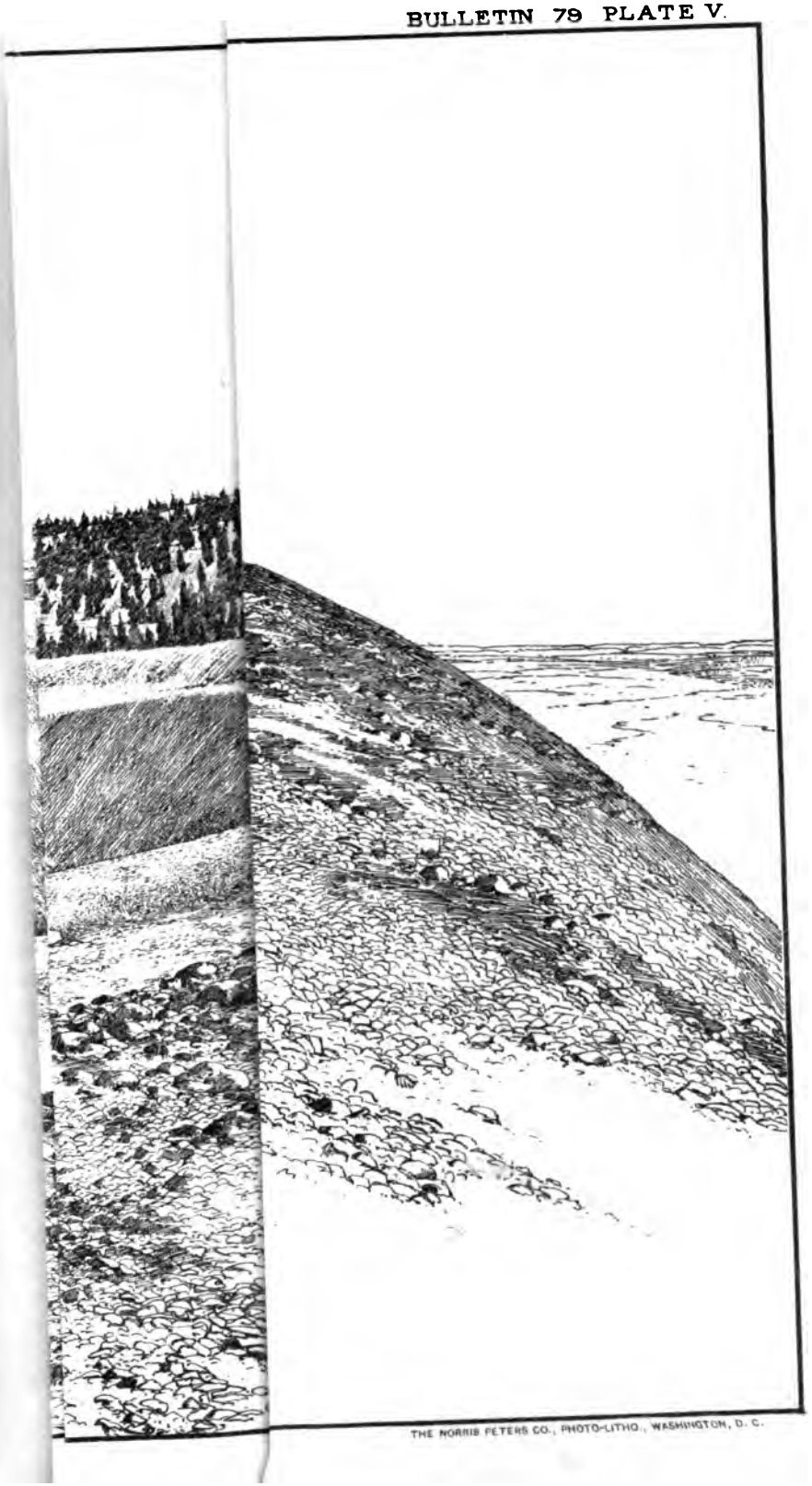
The sand exhibits irregular stratification due to the assorting action of the atmosphere upon the subsiding particles during the eruption. The thin layers are lenticular in shape and continuous for short distances only, not as sharply defined as beds laid down in water, but indicating a decided tendency to form beds under unfavorable conditions. This tendency is most clearly manifested a short distance away from the volcanic vent where the air was not so much disturbed by the violent current expelled from the crater.

The selective influence of the atmosphere may be seen not only in the imperfect stratification of the sand as exhibited in a vertical section, but also in its distribution upon the surface. Near the cinder cone the sand is coarse and the bed thick, but it becomes thinner and the sand finer and finer as the distance from the cone increases.

On the borders of the large circular field covered by the sediment thrown out from the crater the fine material is sand, and there is no evidence to show that any considerable amount of volcanic dust or material still finer than the finest sand was formed.

The almost complete absence of volcanic dust in this case is surprising when we consider the highly explosive character of the eruption, and it may be attributed in part, perhaps, to the viscous condition of the magma at the time of the outburst. Had the pumiceous fragments in the layer already referred to contained sufficient eruptible gases at the time of the ejection to blow them to atoms, considerable dust would doubtless have resulted.

The variety in the fragmental material ejected from the volcanic vent is not in size alone but also in form and structure. The larger fragments as well as the smaller particles violently hurled into the atmosphere while yet in a highly heated viscous condition show a tendency to assume a spherical form. Their vesicular structure renders them more brittle, so that in the violent collisions of the ascending and de-



THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

scending fragments many of them were reduced to smaller pieces which, although at first angular, may, as in the sand blast, become rounded by the frequent attrition of neighboring particles. In the sand the rounded forms, both original and abraded, as well as the angular chips and splinters, are abundant, with many intermediate grades.

The lapilli differ from the sand particles chiefly in size, but it is true in general, also, that they are more rounded and less vesicular, while the volcanic bombs, which are the largest fragments, found only at the base of the cinder cone, are all rounded and compact, excepting upon the periphery, where they may be more or less scoriaceous.

The vesicular covering of the bombs shows that their form is not due to the impact of neighboring particles, but to some earlier cause. Some of these bombs are over 8 feet in diameter, and it is difficult to believe that they became round and cool while flying through the air, for that would postulate an unreasonable rapidity of cooling. That they were solid when they struck the ground is evident because they did not flatten as did those ejected from the Mono Craters and many others. It appears probable that these large bombs were the first part of the lava to solidify, and were suspended in the magma before the eruption, when they were hurled out of the crater in their present form. This view of their origin explains also their compact structure as compared with the vesicular character of the other ejected material.

THE LAVA FIELD.

The tabular form of the lava field is illustrated in Figs. 1 and 2. It ends upon all sides abruptly like a terrace, frequently over a hundred feet in height. Plate VI shows its termination at the northwest corner of Snag Lake. Notwithstanding its general form, the lava field is full of irregular depressions, slight ridges and peaks, which are so extremely rough as to defy adequate description. Its surface is composed of sharp, angular blocks of lava loosely piled together so as to be completely impassable to many animals. The fragmental character of the lava field resulted from its extreme viscosity at the time of the eruption. The crust was repeatedly broken up by the friction and pressure of the moving viscous mass beneath and shoved along as a huge stone pile. Remnants of broken lava tubes may yet be recognized here and there in the lava field, often with hackly, jagged, steam-torn surfaces. (Pl. VII.)

From the base of the cinder cone where the lava burst forth, by means of small ridges thrown up on the sides of the lava stream in a manner somewhat allied to that in which a glacier piles up its lateral moraines, as well as by the direction of the exposed lava tunnels and the flow-curves moved along on the surface of the current, its course can be traced first to the southeast, then bearing rapidly to the east, northeast, and north until finally part of the stream moved in a northwesterly direction, traversing a distance of not less than 3 miles, and

yet at last coming to rest within one and a half miles of the vent. This was the route of the latest flow, and its course was greatly modified by the barriers formed of an older lava from the same vent.

A large part of the area now occupied by the lava field was once the site of a lake, which, by the encroachments of the lava, has been reduced to the present Lake Bidwell. At the time of the eruption the steam generated below by the hot lava coming in contact with the lake water burst up through the lava flow, forming miniature fragmental cones or covering the adjacent portion of the lava field with a thin sprinkling of volcanic sand or scoria. The best example of a cone of this sort is in the northeastern quarter of the lava field.

Everywhere in the lava field one is impressed with the idea that the lava moved slowly and with great difficulty, repeatedly breaking its crust and shoving along as a great stone pile, presenting an abrupt, terrace-like front upon all sides. It is a typical example of a lava field formed by the effusion of a viscous lava on gentle slopes. Had it been highly liquid like many of the other basalts in the same great volcanic field it would have found egress at the outlet of Lake Bidwell and stretched out down the little valley for miles northward.

The lava on the whole is decidedly compact as compared with others which are regarded as prominently vesicular, and yet in many parts it is full of small cavities. These cavities, however, are irregular in shape and with but little of the dense, often glassy, lining that generally surrounds the nearly spheroidal bubbles or vesicles in liquid lavas. These may have been filled with gas under high pressure, but of this there is little evidence to be found in the form or surroundings of the vesicles themselves. Perhaps this may be attributed to the highly viscous condition of the lava on account of which it was not susceptible of slight rearrangements in response to the pressure of the included gas. That the cavities were actually filled with gas under pressure is indicated by a study of the extremely rough, hackly surfaces of the lava tubes which were torn by the eructations of gas from such cavities. The liquidity of lavas has been frequently attributed to the presence of water, and perhaps the absence of a large amount of water in this case will explain its high degree of viscosity.

There is another consideration, however, to which attention must be given and that is the temperature. The temperature of lavas at the time of their eruption can be determined relatively only by studying the effects of their heat upon the adjacent rocks, the amount of contraction they have experienced in cooling, and their degree of crystallization. It is generally true that the lavas which were at the time of their eruption most liquid so as to spread far and wide over the country like sheets of water, as is true in many places in the great volcanic region of the northwest, are most crystalline, frequently holocrystalline and do not show, excepting at the upper surface, any evidence of the presence of considerable water or gases included in them. It is most

THE EDGE OF THE LAVA FIELD AT THE NORTHWEST CORNER OF PAO LAKE

THE SURFACE OF THE LAVA FIELD, SHOWING BREAKING OF THE CRUST.

commonly true, also, that the extravasation of the most liquid lavas is unattended by explosive eruptions which are the special manifestations of steam. It may be possible, therefore, that water has less to do than is generally supposed in producing (1) the high degree of liquidity in some lavas and (2) their effusion.

The holocrystalline basalts which at the time of their eruption were very liquid are commonly found upon close examination to have a decidedly cellular structure. The cells are interspaces left between the crystals by contraction in the process of cooling and are evidence that the liquid lavas had a very high temperature when effused. Other things being equal the higher the temperature of the magma the longer it will take to cool and the better it will crystallize. Thus the liquidity and the degree of crystallization of basaltic lavas are proportional to the temperature of their eruption. The lava from the Cinder Cone contains a large proportion of amorphous matter and exhibits no traces of cellular structure arising from contraction in the process of cooling.

As already stated there were two eruptions at the Cinder Cone. The earlier lava is mantled by a shower of sand but the latter is not. The surfaces of the two lava flows may be readily distinguished in Pls. VIII and IX. The depth of the lava varies somewhat in different parts of the field. It is frequently much over 100 feet and averages nearly that amount. The relations of the two lava flows, the mantle of sand by which they are separated, and the deposits of the ancient lake are illustrated in the accompanying section (Pl. X).

ANCIENT LAKE BED.

The ancient lake bed is exposed about the northern end of the lava field and upon the shores of Lake Bidwell, as illustrated on the map (Pl. XI). It connects directly with the present bottom of Lake Bidwell and the evidence indicates that the lake in which it was laid down covered a large part of the area now occupied by the lava field. There is no visible evidence to show clearly where its southern shore was, and before the eruption it may have extended nearly as far south as Snag Lake.

The bed is soft, white, and earthy, composed chiefly of infusorial earth intermingled with vegetable matter, such as grows on lake bottoms, and a small percentage of sediments washed in by little tributary streams. The thickness of the lacustrine deposit is at least 10 feet and it is well exposed at several points. That it immediately underlies the later lava flow is plainly seen upon all sides, and that it originated since the older lava is shown by the fact that it rests upon the volcanic sand which covers the older lava. There are several small areas of the old lake bed within the northern portion of the lava field, but accurate data for their location were not obtained.

To determine the relations of the old lake deposit to the sheet of volcanic sand a trench was dug across their junction near the west end of

Lake Bidwell and it was found that not less than 10 feet of lake deposit rested upon the sand.

Another feature of interest associated with the present lakes is the snags they contain. In Snag Lake (Pls. XII and XIII) they were once abundant but are now less so, many having been blown down and floated ashore. A few are found also near the east end of Lake Bidwell. The snags are evidently the trunks of trees killed by having their roots submerged. Near both ends of Lake Bidwell the old lake deposits rise above the present level of the lake, but at the point where the snags appear Lake Bidwell has advanced upon the forest and shows that the shore of the old lake was warped so that it does not lie parallel to the water surface of the present lake.

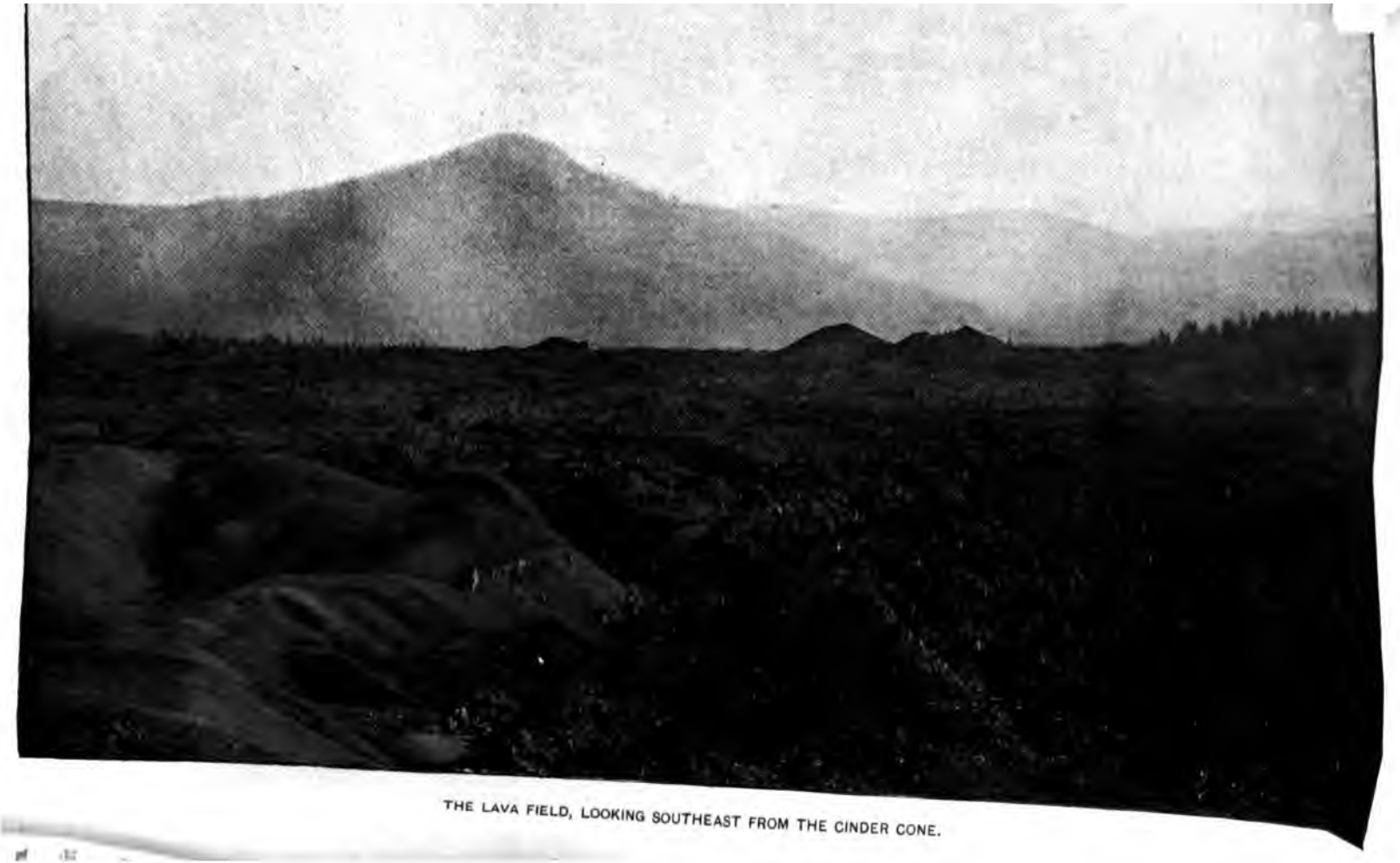
Lake Bidwell has a free outlet and rises during the rainy season only a few feet above low-water mark. On the other hand, Snag Lake has no free outlet and all its water, excepting that lost by evaporation, must escape through the lava field. During the rainy season, on account of the barrier which the lava imposes, the water of Snag Lake rises over a dozen feet. Upon its southwestern border the lava field forms two other small basins each of which contains a lake in wet weather.

HISTORY OF THE ERUPTION.

The history of this little volcano shows two periods of activity strongly contrasted in their phenomena and separated by a considerable interval of repose. The first period was characterized by violent explosive eruption, which formed the Cinder Cone and the ash field, and the second by the quiet effusion of a large mass of lava.

The first eruption began with the ejection of a great deal of light scoriaceous, almost pumiceous material, thrown out from the upper part of the magma, in which was stored a larger proportion than elsewhere of the highly expansible gases. When the passage to the surface was opened and the pressure relieved, this portion of the magma was much more highly dilated than any other. The expansion and disruption, however, were not sufficient to produce an appreciable amount of volcanic dust—a phenomenon which was a prominent feature of the late outburst at Krakatoa, sending its dust wafted on the winds for many hundreds of miles away. Succeeding the eruption of the pumiciform material, and continuous with it, came the volcanic sand, lapilli, scoria, and bombs from the next succeeding lower portion of the magma, containing a smaller amount of eruptible gases, but yet sufficient to tear it to pieces and hurl them into the air.

After the greater portion of the fragmental material had been ejected there was an effusion of considerable lava from the base of the Cinder Cone, and this effusion was accompanied and succeeded by a shower of sand which formed a thin coating over the lava already effused. Whether or not the effusion of the oldest lava and the succeeding



THE LAVA FIELD, LOOKING SOUTHEAST FROM THE CINDER CONE.

THE CINDER CONE, LOOKING WEST; OLDER AND NEWER LAVA IN THE FOREGROUND.

shower of ashes belong to the closing stages of the first eruption is not easily determined, but it is certain that all these preceded the long interval which separated the period of explosive eruption from the succeeding one of quiet effusive activity. During this interval of repose the old lake beds of infusorial earth and vegetable matter were laid down to a thickness of over 10 feet, and may represent a century or more of time.

This season of volcanic rest was again broken by the warping of the old lake bottom and the slow effusion of a great volume of very viscous lava from the southeastern base of the Cinder Cone. The new flow of lava developed the tabular lava field filling the shallow valley and forming the lava dam (Pls. XII and XIII) which gave birth to Snag Lake. A remarkable characteristic of the eruption was the entire absence of any explosion from the crater in connection with the effusion of so large an amount of very viscous magma, especially since the same vent at an earlier period had been the scene of violent ejection.

AGE OF THE ERUPTION.

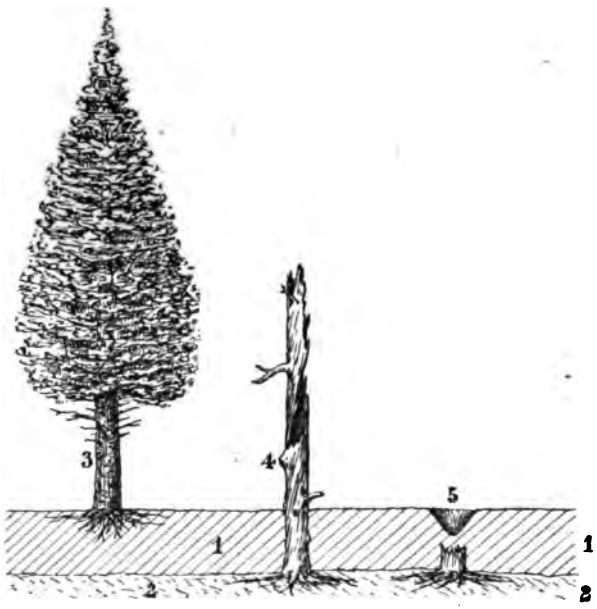
The whole aspect of the Cinder Cone and lava field is so new that one at first feels confident of finding historic evidence of its eruption. To say that it was formed in the geologic yesterday, even, makes it too old, for it appears rather to belong to the early part of to-day. Some trees near the lava look as though they had been scorched by it at the time of the eruption, and visitors to the scene have conjectured that search would reveal volcanic ashes still clinging in the knot holes, crotches, and other lodging places among the adjacent forest trees. The investigation by Dr. H. A. Harkness, of San Francisco, concerning the age of the outbreak has been published,[1] and he infers, upon historic evidence of a very unsatisfactory character, that the eruption took place in January, 1850.

I have carefully sought among the earlier settlers, as well as among the Indians of that region, for positive historic evidence concerning the date of the eruption, but the only trustworthy testimony obtained is of a negative character. No white man or Indian now living is known to have been an eyewitness of the eruption, and it must be remembered that such an eruption would not leave the people of the region in doubt as to what was happening. What is now generally known in the Lassen Peak district as the Cinder Cone, was among the earliest settlers and trappers, as far back as 1845, called Black Butte. An old emigrant road yet in use passes by the very base of the Cinder Cone, and a number of individuals are living in the northern portion of the Sacramento Valley who crossed the trail in 1853, and report that the lonely bush growing near the summit of the cone was apparently as large then as now. Whatever may be the historical testimony as to

[1] Proc. Cal. Acad. Sci., Nov. 2, 1874, vol. 5, p. 408. See also article by Capt. C. E. Dutton, Science, July 17, 1885, vol. 6, p. 46.

the time of the eruption, the geologic evidence clearly demonstrates that it must have occurred long before the beginning of the present century.

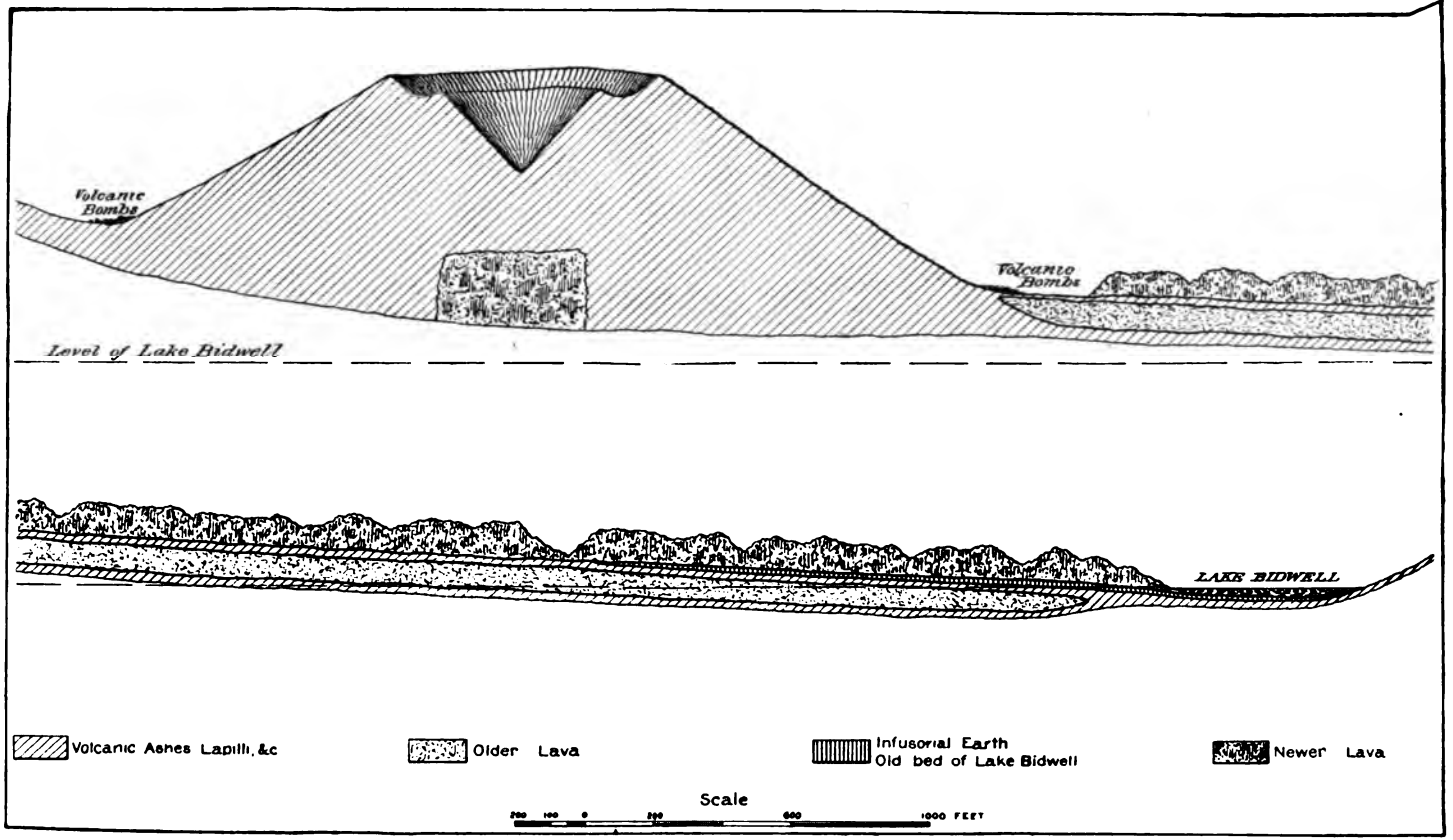
Plate XIV shows the upper portions of a tree projecting from beneath the lava. The top has been broken off and lies upon the ground. The tree was pushed over by the advancing lava and apparently belongs to those killed at the first eruption when the Cinder Cone was formed. Two other trees of the older generation are seen in the view. The dead one on the left extends for a distance of more than ten feet down through the layer of volcanic sand to the original soil beneath, but the living trees in the neighborhood grow in the new soil upon the surface of the volcanic sand. They do not extend their roots more than three feet beneath the surface. The relation of the two distinct generations of forest trees is represented in Fig. 3. As the stumps of the trees killed at the time of the earliest eruption decay the sand caves in to take the place of the wood and forms a pit, as illustrated in the figure.



1 Volcanic Ashes Lapilli &c
2 Original soil.
3 Present forest tree
4 Tree of former forest killed by shower of Volcanic Ashes Sand &c.
5 Pit formed by the decay of old forest tree.

FIG. 3.—Relations of older and younger forests to volcanic sand.

These pits, often three feet deep, are numerous near the base of the *Cinder* Cone, and may be observed, at least to the southwest, for a distance of one and a half miles from the cone. The new forest has



SECTION THROUGH THE CINDER CONE, LAVA FIELD, AND LAKE BIDWELL.

attained its maximum growth for that region and there is no appreciable difference between it and the forest farther away from the Cinder Cone. Southwest of the Cinder Cone, however, as shown in Pl. XV, the new forest has a feebler development than elsewhere.

Several of the largest pine trees (*Pinus ponderosa*) in the vicinity of the Cinder Cone were measured two feet above the ground and found to be twelve feet in circumference, with a diameter, therefore, of forty-five inches and a thickness of solid wood of not less than forty-three inches. Not many miles to the westward from the Cinder Cone, where the climatic conditions are about the same, the heavy yellow pine is cut for lumber. The rings of growth were counted upon numerous stumps and it was estimated that the large pines near the Cinder Cone must have not less than 200 rings of growth. There is but one season of growth and one of repose for each year in that mountainous region, and there is good reason, therefore, for supposing that each ring represents a year's growth. If so, the trees by the cone must be about 200 years old. Presumably, as is well known to be true in other cases, the vegetation would take hold upon the volcanic sand very soon after the eruption, so that the age of the oldest trees may be taken as a rough approximation to the age of the first eruption, and we may with some reason conclude that it occurred nearly a century before the American Revolution. The second or effusive eruption occurred at a much later date, but certainly more than fifty years ago, and was of such a character as not to attract attention.

Upon the older portion of the lava southeast of the Cinder Cone a few pine trees have taken root. The largest has a diameter of one foot and over ninety rings of growth. Upon the newer lava near Lake Bidwell some scattered cottonwoods are growing. One shows over fifty rings of growth. It is interesting to note that dead pine trees, which are not usually supposed to maintain their form through more than thirty years of weathering, in this case have stood over 200 years. This may be attributed in large measure to the dry climate.

THE LAVA-QUARTZ BASALT.

The lava is readily recognized as basalt, one of the commonest of all types of late volcanic rocks, with hypocrystalline porphyritic structure. It has all the essential constituents of ordinary basalt, i. e., plagioclase feldspar, pyroxene, and olivine, together with accessory magnetite, and a large proportion of unindividualized material which is generally globulitic. In addition to all these common constituents of basaltic lava this basalt is remarkably anomalous in containing numerous grains of quartz.

The conditions under which the molten magma, erupted at the Cinder Cone, solidified to form the lava, were diverse at different places, and the physical features of the lava are varied accordingly. It ranges in structure from the highly *vesicular in* the pumiceous fragments spread

beneath the sand to the very compact lava seen in some of the larger bombs and here and there throughout the lava field. Much the larger portion of the lava is somewhat vesicular, but the vesicles are small and irregular, so that the lava could not be classed among those which are prominently vesicular. The lava is wholly hypocrystalline, but ranges from almost completely amorphous to largely crystalline, and the degree of crytallization is in general inversely proportional to the vesicular structure.

The light brown color of the pumiceous fragments is due to the presence of so much inflated glass whose color by transmitted light gives tone to the whole mass. Under the microscope it is seen that grains of olivine are numerous, some of them are well developed crystals and full of picotite. Rounded grains of quartz and clouded crystals of feldspar comparatively large are much less common. In the brownish glass are embedded a multitude of feldspar and augite microlites, occasionally having a stream-like arrangement about the minerals of the first generation. Many vesicles of various sizes are visible in the section and each one has a smooth, glassy lining. Of all the lava this was cooled the most suddenly. It contains the fewest products of crystallization, and indicates that in the upper portion of the magma, which was saturated with water under great tension awaiting the outburst, the olivine was already completely formed. The same is true of the quartz and the larger clouded crystals of feldspar, all of which have undergone partial resorption by the magma. On the other hand, while the eruption was in progress and the lava cooling many tiny crystals of feldspar and pyroxene were formed.

The lapilli are black and less vesicular than the pumiceous fragments, and differ from them chiefly in having a smaller amount of less glassy groundmass. The lath-shaped feldspars and grains of pyroxene have greatly increased in size and number so as to become conspicuous. The dark groundmass is full of colorless microlites mixed with minute black and cherry-red grains of iron oxide which are enveloped by a clear or clouded light brown occasionally globulitic base. The most vesicular portion of the lava cooled near the surface. It is extremely rough and cindery owing to the eructation of steam and other gaseous matter from the vesicles lying near the surface.

Although much less porous than the lapilli, it contains a much larger percentage of light brown glass and in this respect is very like the pumiceous fragments. A short distance beneath the surface the lava becomes more crystalline. The crystals and crystalline grains are larger, and the glassy base gradually arranges itself in minute spheres until it is completely replaced by a multitude of dark globulites.

The most highly crystalline lava was found along the southwest border of the lava field one-third of a mile south of the Cinder Cone. It is the portion best adapted for the study of its minerals.

Of the mineral constituents of the lava the feldspar is most abundant; then follows the pyroxene in a nearly equal amount with less olivine,

and finally quartz. Abundantly scattered throughout the rock and filling the spaces between the minerals is a dark globulitic base, which makes up nearly 25 per cent of the mass.

Some of the olivine occurs in well defined crystals bounded by the usual prismatic and pyramidal planes, but by far the greater portion appears in round or irregular grains. It envelopes a large number of regular octahedral crystals and grains of a coffee-brown mineral, which is supposed to be picotite. Glass and liquid inclusions are also common, and the olivine is much fractured. That the olivine is one of the oldest minerals of the basaltic magma is clearly indicated by the fact that it is included in both feldspar and pyroxene. Granules of the latter sometimes appear to be most abundant upon the borders of the olivine in such a way as to recall a hypothesis advocated by Dr. M. E. Wadsworth[1], to the effect that a part of the pyroxene in basaltic rocks owes its genesis to the resorption of an earlier generation of olivine. Some of the olivine is so intercrystallized with the pyroxene as to indicate that both are in part of essentially the same age. The familiar black border which is a common feature of the olivine in many basalts is generally present in the central portions of the volcanic bombs, but has not been observed in any portion of the lava field.

The pyroxene is chiefly hypersthene, but augite also is sparingly present. The pyroxene is more abundant than the olivine, but less so than the feldspar, a feature which prevails among the andesitic basalts of the Cascade Range. The hypersthene is sometimes completely idiomorphic, but commonly only partially so, being allotriomorphic against the feldspar. The crystals are short, rather thick prisms less than two-tenths of a millimeter in length. As in the hypersthene andesites long ago pointed out by Dr. C. W. Cross,[2] the lateral pinacoids are largely developed and generally predominate over the prism planes. Obtuse pyramidal terminations were also observed. This hypersthene has a faint reddish yellow tone with perceptible pleochroism, which assists in distinguishing it from augite. It occasionally contains numerous irregular glass inclusions which permeate the interior portion of the crystal, but not so completely as in the first generation of feldspar. Some of the pyroxene is irregularly granular, and the system of crystallization is determined with difficulty. There are more or less completely developed crystals whose monoclinic character is evident, but much the larger number of grains appear to be orthorhombic. The most noteworthy feature of the monoclinic pyroxene is the granular borders which it forms about the grains of quartz. These are described and figured in connection with the quartz page.

The feldspar is of two sorts, and both are idiomorphic. The one occurs in relatively large, irregular crystals with clouded interiors; the other appears in sharply defined, lath-shaped polysynthetic twins, which predominate in rocks of this class and present no features worthy

[1] Bull. Mus. *Comp. Zool.*, Cambridge, Mass., 1879, vol. 5, p. 279.
[2] *Bull. U. S. Geol. Survey, No. 1*, 1883.

of special mention. The irregularities of the clouded feldspars are due in part to crystallization and in part to the subsequent corrosive action of the magma which modified the original form. In some of them the interior is completely ramified by glass and globulitic inclusions. The outer zone of such crystals is usually clear and free from inclusions. These larger crystals are nearly all polysynthetic twins, with broad lamellæ, but their impure condition renders an exact determination impracticable.

Notwithstanding the strong contrast there is between the two sorts of feldspar in general, there are a few forms intermediate in size and general appearance so as to connect the generation of feldspars formed during the intratelluric period of the magma with those developed during its effusion.

THE QUARTZ OF THE QUARTZ BASALT.

The most interesting feature of this basalt is to be found in the remarkably large percentage of quartz which it contains, widely distrib-

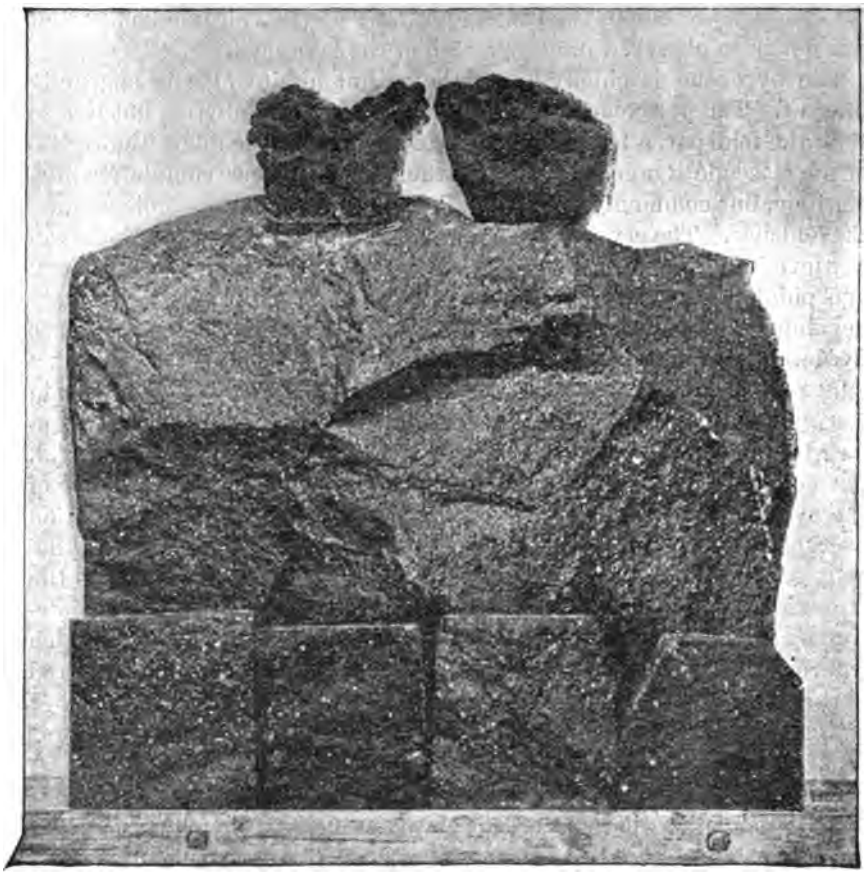


FIG. 4.—Specimens of lava containing quartz, from all parts of the lava field.

THE LAVA DAM AND SNAG LAKE, NEAR VIEW.

uted through the mass. The quartz grains are in fact frequently so abundant as to impart a decidedly porphyritic structure to the mass, but generally they are so small as to be inconspicuous. Very rarely grains may be found over an inch in diameter. The average diameter is about one-thirtieth of an inch. Those lying near the surface of the lava flow are fractured, sometimes breaking into small prisms, but in the interior portion of the lava fractures are absent, a feature which suggests that they were produced by sudden cooling.[1]

The uniform distribution of the porphyric grains of quartz throughout the lava can be plainly seen in Pls. XVI and Pl. XVII, and also in Fig. 4, which represents fragments from all parts of the lava field. That the quartz is equally scattered in the lava is shown even more forcibly by the thin sections, of which over fifty distributed throughout the lava mass have been examined microscopically, and the presence of quartz is evident in nearly every section. The same fact is impressed by the chemical analyses not only of the lava from various portions of the lava fields, but also of volcanic bombs and sand at different distances from the Cinder Cone.

The quartz grains are irregular in shape, frequently angular, but generally rounded and embayed as the phenocrystic[2] quartz in other lavas. Notwithstanding the large number of sections examined, not a single idiomorphic crystal of quartz was found. All have been greatly modified apparently by the corrosive action of the magma. From a hand specimen, however, one crystal was obtained, which, although somewhat rounded, yet retains distinct traces of its former bipyramidal form. It is probable, therefore, that originally a large number of the included grains of quartz may have been dihexahedral crystals just as in other eruptive rocks.

Each grain of quartz, excepting those in the pumiceous fragments, is encircled by a shell of granular, acicular augite, which is separated from the quartz by a film of glass. In Pl. XVII, Nos. 1 and 2, such quartz grains are represented. The irregular grains of quartz in the center are surrounded by glass, which is darkened in the figures, and outside of this is the more or less radially granular or acicular augite. The borders of glass and augite are constant features of the quartz, and appear to be reactionary rims resulting from the corrosion of the quartz by the magma.

The resorption of the quartz is partial only. The great majority of the grains have only their outer portions removed, but there are many others which have nearly or completely disappeared. In Pl. XVII, Nos. 3 and 4 represent grains of quartz which have almost disappeared. Only small portions of the original quartz remain imbedded in the glass. In No. 5 the quartz has entirely disappeared, and in No. 6 the glass has gone also, leaving a group of augite crystals to tell the story. In

[1] Rosenbusch, Mik. Physiographie, vol. 2, p. 356.

[2] For the use of the term "phenocryst," see Mr. J. P. Iddings's paper on the Crystallization of Igneous Rocks, Phil. Soc. of Washington, D. C., *Bulletin*, vol. xi, p. 73, foot-note.

this way are produced structures which appear in most cases at least to be identical with the so-called "augite eyes" (Augitaugen[1]) which are well known in a number of European basalts.

The quartz is colorless and transparent with few liquid or gas inclusions. Glass inclusions are more abundant but are rarely dihexahedral. They are most common in deeply embayed grains, and appear in many cases to be of secondary origin like those described by Crustschoff.[2] In its essential features the quartz in the basalt is identical with the phenocrystic quartz of the dacites and rhyolites and differs decidedly from granitic quartz and that of the crystalline schists.

The glass border with which the quartz grains are surrounded is generally colorless and transparent, but occasionally it is brown. In the highly vesicular lava the glass rims generally contain bubbles. These are sometimes so numerous as to render the glass pumiceous. Among the lapilli of the Cinder Cone and in the volcanic sand small fragments of white pumice are not uncommon, and upon examination some of them are found to be almost wholly pumiceous glass containing remnants of quartz and feldspar.

A chemical analysis of one of these enveloped fragments of white pumice is given in column 10, p. 29. Whether the fragment is an inclusion or an early secretion which has been fused and inflated is not easy to determine.

The pyroxene of the border about the quartz may be well crystallized or irregularly granular. Rather long thin crystals are most numerous and frequently converge, penetrating the glass toward the disappearing quartz in such a way as to indicate the direction of their growth.

The small crystals have a large angle of extinction and evidently belong to the monoclinic pyroxenes. They have much stronger double refraction than the hypersthene.

The pyroxene border is epigenetic, and it formed during the effusion of the lava, for it is certainly one of the latest developments in its own neighborhood, and the fact that it is sometimes absent about quartz grains in the pumiceous fragments clearly shows that the sudden eruption and cooling of that portion of the magma prevented its development.

This long thin monoclinic form of pyroxene appears to be found only in groups and owes its existence to the destruction of quartz. It may, perhaps, be closely related to the so-called porricin of the Eifel lavas.

Only four hypotheses suggest themselves in explanation of the origin of these quartz grains in the basalt. They may be regarded (1) as remnants of a rock from which the basalt may have been derived deep in the earth by fusion; (2) as included fragments picked up by the way as the lava was passing from the interior of the earth to its present position; (3) as products of crystallization in the magma itself; and

[1] Rosenbusch, Mikroskopische Physiographie d. Massigen Gesteine, 2d ed., vol. 2, p. 727.

[2] Tschermak's mineralog. und petrog. Mittheil., 1882, vol. 4, p. 473.

(4) as secondary products resulting from metasomatic changes in the lava since its eruption.

The lava is absolutely fresh and unaltered, so as completely to negative the view which regards the quartz as a product of metasomatic changes.

Concerning the first hypothesis, it may be said that there are many prominent geologists who incline to the belief that eruptive rocks originate in the fusion of deeply buried sediments. As already indicated, in unaltered eruptive rocks there are two petrographic types of quartz. The oldest generation of quartz crystals in eruptive rocks is characterized by idiomorphic or corroded outlines and glass inclusions often dihexahedral like the host, with some liquid inclusions. Quartz of this sort always occurs as phenocryst in the rock, and its associations clearly demonstrate that it crystallized out of a molten magma at great depths within the earth.

The quartz in a normally developed granite is the last product of crystallization, filling out the spaces between the crystals of other minerals. It differs from phenocrystic quartz in being allotriomorphic, without glass inclusions, and in containing in general a greater abundance of liquid inclusions. It is the characterizing quartz of granitic rocks, and on that account Rosenbusch has designated it as granitic quartz.[1]

Granitic quartz is closely allied to vein quartz, and that which occurs in metamorphic rocks and bears the impression of having been deposited under condition more of aqueous solution than of igneous fusion.

The quartz of the basalts is not of the granitic phase which pervades sedimentary rocks, but wholly of the phenocrystic type, whose pyrogenic crystallization is evident, and its essential features decidedly negative the view which regards it as the unfused remnant of a sediment.

As to the second hypothesis, which surmises the quartz grains to be included fragments picked up by the lava along the walls of the volcanic chimney or upon the surface of the earth during its effusion, the considerations already mentioned are of great weight. The quartz is not of the type which prevails in sedimentary rocks through which the magma passed on its way to the surface, but of the type whose origin is intratelluric, the very source of the lava itself.

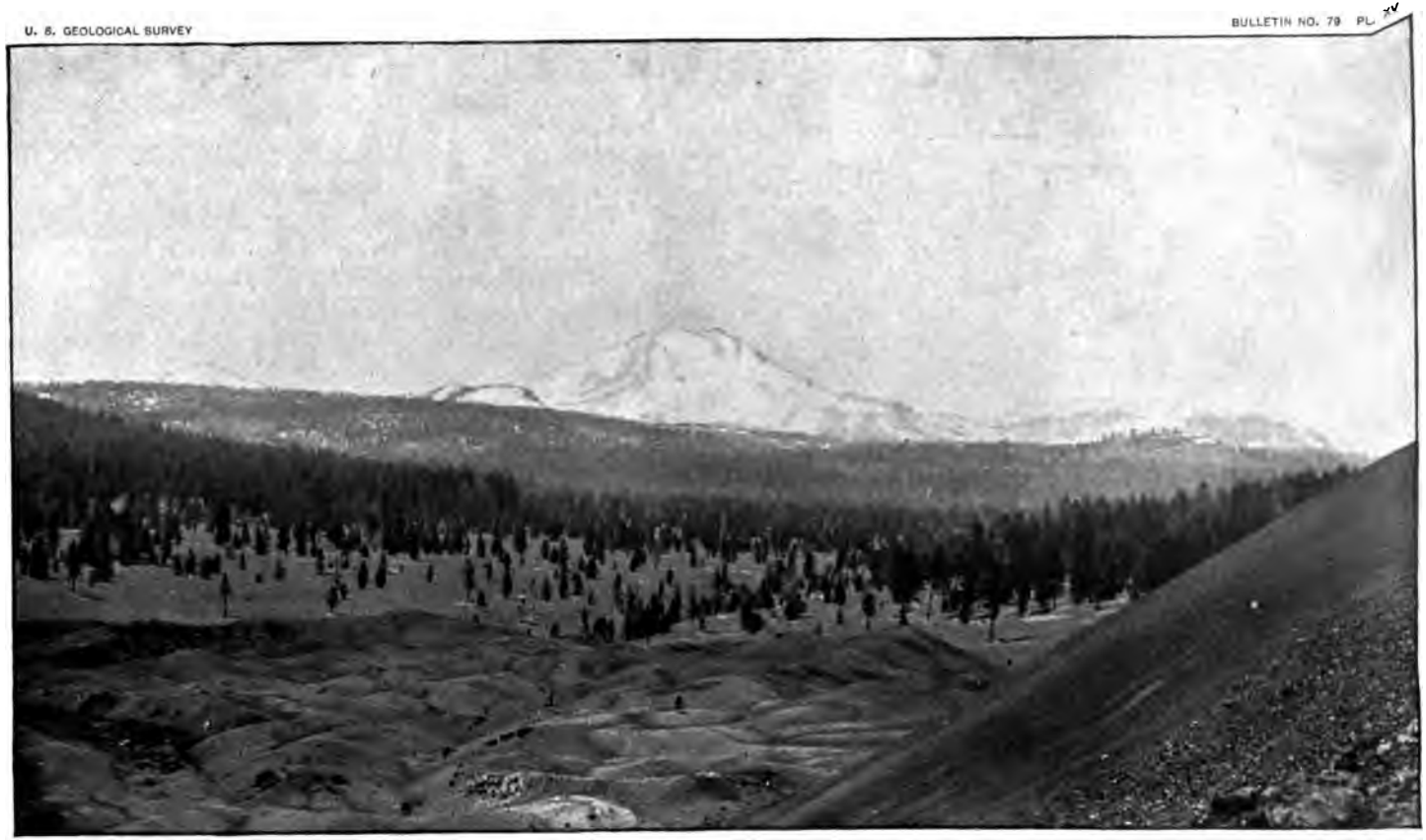
Besides the quartz basalt, the only other lava of the Lassen Peak district that contains phenocrystic quartz is dacite. It is true that the dacites are all older than the quartz basalt, and that the latter may have reached the surface by breaking through the dacites from which perhaps the phenocrystic quartz could be derived. Quartz is more abundant in the basalt than in the dacite, and the amount of dacite that would have to be ransacked to raise quartz sufficient to stock the quartz basalt would be much larger than the mass of the quartz basalt itself.

[1] Rosenbusch, Mikrosk. Physiog., 2d edition, vol. 1, pp. 340–342.

Veritable inclusions in the quartz basalt have been diligently sought for and almost in vain. Only one small fragment of dacite was found in the basalt. It was a fragment picked up upon the surface and showed no tendency whatever to yield up its quartz to the basalt. Furthermore, there are in the same region numerous cinder cones and flows of basaltic lava which have penetrated the same formation to reach the surface as did the quartz basalt, and if the quartz grains are inclusions, all the basalts of that immediate vicinity ought to be quartziferous.

It has been urged that the envelope of pyroxene encompassing the grain of quartz characterizes them as included fragments. All the quartz grains in the magma, whether native (indigenous) or foreign (included) to the lava at the time of its effusion, would be subjected to the same conditions. All would be corroded by the magma and each have its reactionary rim of pyroxene formed, so that the presence of such a border can not be used as a means of distinction. This envelope is absent from the phenocrystic quartz in the quartz porphyries, rhyolites, and generally also in the andesitic rocks; but the above is true also of quartz inclusions in the same lavas. The presence or absence of an envelope of pyroxene is not determined by the source of the quartz, but by the chemical composition of the basic magma which corrodes it.

The uniform distribution of the quartz grains throughout the lava is an insuperable objection to regarding them as inclusions. They are found not only in all parts of the lava field, but everywhere in the Cinder Cone and throughout the volcanic sand. Their distribution is universal, like that of the olivine, pyroxene, and feldspar, and it is impossible to satisfactorily explain their omnipresence on any other hypothesis than that they are indigenous to the lava and crystallized out in place, belonging to the basalt and forming an essential part of it, just as much as the olivine, feldspar, and pyroxene.



OLDER LAVA, ASH FIELD, AND LASSEN PEAK, FROM THE SOUTH BASE OF THE CINDER CONE.

Chemical analyses of volcanic product.

	1	2	3	4	5	6	7	8	9	10
SiO_2	56.18	57.25	54.56	56.70	56.53	55.93	57.59	56.51	56.58	79.49
TiO_2	16.59	0.60	0.53	0.65	0.54	17.34	16.49	0.48	0.77	*11.60
Al_2O_3		16.45	16.04	15.75	17.50			18.10	14.88	
Cr_2O_3	.....	.....	trace.	trace.	trace.	.....	.....	trace?	trace?	.....
Fe_2O_4	1.51	1.67	0.95	1.29	1.35	1.50	1.22	4.26	2.31	0.33
FeO	5.51	4.72	6.07	5.32	5.03	5.20	4.89	2.68	3.04	0.49
MnO	undet.	0.10	0.17	0.19	0.12	undet.	undet.	0.11	0.16	none.
CaO	7.64	7.65	8.89	7.67	8.07	8.04	7.40	8.15	8.69	1.64
SrO		trace.	trace.	trace.	trace?	.....		0.04	.....	
BaO		0.03	0.03	0.03	trace.	(?)		0.04	0.07	
MgO	7.26	6.74	8.71	7.16	5.94	7.29	7.72	4.52	3.76	0.09
K_2O	1.47	1.57	1.18	1.56	1.55	1.35	0.99	1.15	2.18	1.52
Na_2O	3.58	3.00	3.05	3.36	3.51	3.32	3.62	3.23	3.36	4.04
Li_2O		none.	trace.	trace.	trace.	(?)		trace.	CO_2 2.32	
H_2O	0.42	0.40	0.28	0.30	0.27	0.26	0.86	0.69	2.12	0.68
P_2O_5	with Al_2O_3	0.20	0.18	0.20	0.15	with Al_2O_3	with Al_2O_3	0.14	0.15	.....
	100.16	100.38	100.64	100.18	100.56	100.23	100.78	100.10	100.39	99.88

* Contains P_2O_5 if any present.

1. Lava from west end of Lake Bidwell. Analyst, W. F. Hillebrand.
2. Lava near Cinder Cone. Analyst, W. F. Hillebrand.
3. Lava from point ½ of a mile south of Cinder Cone. Analyst, W. F. Hillebrand.
4. Volcanic bomb. Cinder Cone. Analyst, W. F. Hillebrand.
5. Lapilli. Cinder Cone. Analyst, W. F. Hillebrand.
6. Volcanic sand. One-half mile NE. of Cinder Cone. Analyst, W. F. Hillebrand. Sand from 10 miles NE. of Cinder Cone contains 54.15 per cent of silica. Another sample, ½ mile, contains 54.96 per cent, SiO_2. Determined by E. L. Howard.
7. Lava from Silver Lake, Cal. Analyst, W. F. Hillebrand.
8. Lava from north base of Lassen Peak. Analyst, W. F. Hillebrand.
9. Lava from Mytilene. Analyst, T. M. Chatard. This specimen contains also CO_2=2.32, H_2O at 105°=.69, at red heat, 1.43°.
10. White pumiceous fragment enveloped by lava at the base of the Cinder Cone.

The chemical analyses of quartz basalt given in the accompanying table were made in the laboratory of the U. S. Geological Survey. The first six are of various sorts of material ejected and effused from the Cinder Cone 10 miles northeast of Lassen Peak, California, and they show the remarkable uniformity in the distribution of the silica. The percentage of SiO_2 is high in all of them. The one from the north base of Lassen Peak as well as that from Mytilene is poor in olivine and somewhat andesitic and the latter is considerably altered. Mr. J. P. Iddings demonstrated by chemical analyses of some New Mexican quartz basalts[1] that the presence of phenocrystic quartz in the basalts is not determined by a high percentage of silica in the magma, as one might be led to infer from the analyses in the table above.

The important lesson to be learned from this remarkable basalt is that quartz and olivine in abundance have actually crystallized in the same magma before its eruption. The relative ages of these two min-

[1] Am. Jour. Sci., Sept., 1888, vol. 36, p. 220.

erals are not at first evident, for neither is ever found included in the other. They are not congregative. The quartz is wholly free from mineral inclusions and has been deeply corroded by the magma; on the other hand the olivine contains many crystals of picotite and has suffered comparatively little from the caustic action of the mother liquor. These facts indicate with a high degree of probability that the quartz is older than the olivine. If the amount of corrosion a mineral has experienced may be taken as an index of relative age, it is certain that phenocrystic quartz is one of the very oldest minerals of the lava in which it occurs.

Quartz basalt holds the same relation to the general group basalt as dacite does to andesite and quartz trachyte (rhyolite) to trachyte. Quartz trachytes are very abundant as compared with trachytes. In the basalts, however, the other extreme is reached: the quartz-bearing members are rare while ordinary basalts are the most abundant and widely distributed of all lavas. In the andesites the quartz-bearing and quartzless members are more nearly equal.

DISTRIBUTION OF QUARTZ BASALT.

When the quartziferous character of the basalt at the Cinder Cone was discovered it was regarded as almost unique, but subsequent investigation has revealed the fact that such basalts are by no means as rare as formerly supposed.

In the Lassen Peak district alone they have been effused from four different volcanic vents. At Silver Lake, 25 miles northwest of Lassen Peak, the outburst, although not so recent as that just described, is a late flow, younger than any of its neighbors, and was very viscous at the time of its eruption, forming a lava field nearly equal to that at Snag Lake.

Near the northwestern base of Lassen Peak, northeast of Chaos, at an elevation of about 8,000 feet, there is a small outcrop of quartz basalt, chiefly fragmental, the source of which has not been definitely determined. East of north from Lassen Peak about twenty miles, bordering the valley of Hat Creek upon the east, is an edge of a platform which is well known in that region as Hat Creek Hill. It was formed by a north and south fault and is capped by a basalt which contains occasional grains of quartz. A microscopical examination reveals a number of groups of acicular pyroxene crystals (Augitaugen) which represent resorbed quartz, and it is evident that the magma was once full of quartz crystals which have almost completely disappeared.

At the time of its eruption the lava was very fluent—spreading far and wide almost as level as a sheet of water. It is not vesicular and almost holocrystalline and has a decidedly diabasic structure. In all of these features it is strongly contrasted with the quartz basalt of the Cinder Cone. Both rhombic and monoclinic pyroxene are present. The *former is the older* and idiomorphic; the latter is allotriomorphic and

NEAR VIEW OF LAVA

The white grains are quartz.

largely predominates. Olivine is not abundant and is wholly granular. From the four examples of quartz basalt already discovered in the Lassen Peak district it is very probable that others will yet be found in the same region.[1]

The finding of quartz as a constant ingredient in some of the basalts of the Lassen Peak district has led me to examine many other American lavas of the same class.

While studying the Grand Cañon region, Capt. C. E. Dutton made an extensive collection of basaltic lavas, which are of interest on account of the evidence they furnish concerning the resorption of minerals developed early in the crystallization of the magma. In the newest lava nodules of olivine are abundant, ranging in size from a few inches to a foot in diameter. Corroded crystals of hornblende, quartz, and feldspar are not uncommon. In a few of the sections from the older lavas of Mounts Trumbull and Logan the characteristic augite eyes, both with and without quartz in the center, have been observed.

At the Ice Cave Buttes and Tabernacle Crater, 10 miles west of Fillmore City, Utah, there is a volcanic field described by Mr. G. K. Gilbert.[2] The numerous lava flows are of basalt, which frequently contain quartz scattered throughout the mass. The quartz appears to be most abundant in the newest lava.

In a collection made by Capt. Dutton in the vicinity of Mount Taylor, New Mexico, there are numerous basalts, and among them are specimens containing augite eyes as well as a few grains of corroded quartz, besides rounded and embayed grains of oxide of iron and augite. The most interesting of these late quartz-bearing lavas is in the immediate vicinity of Grant station, on the Atlantic and Pacific R. R. Recently a number of sections prepared from the basalts which form the volcanic necks east of Mount Taylor have been examined, and in some of them there are eyes of pyroxene with here and there a trace of phenocrystic quartz, but in the great majority of basaltic lavas of that region, all of which have passed through the same formations to reach the surface, there is no trace of primary quartz.

Mr. Iddings read a paper before the Philosophical Society of Washington in which he described several specimens of basalt collected by Maj. J. W. Powell and Mr. W. H. Holmes in Northern New Mexico.[3]

These basalts contain numerous grains of phenocrystic quartz, which Mr. Iddings described in detail, and in all essential features they are identical with those in the quartz basalt at Snag Lake. Analyses of the lavas from New Mexico show that in chemical composition they are normal basalts, clearly demonstrating, Mr. J. P. Iddings argued, that

[1] Dr. M. E. Wadsworth informs me by letter (March 26, 1887) that in studying the basalts of California he has found a number of them to contain quartz. In his writings he frequently refers to this interesting phenomenon in other basalts also. "Classification of Rocks," Bull. Mus. Comp. Zool., Cambridge, Massachusetts, vol. 5, pp. 276, 281, 286. "Geology of Iron and Copper District of Lake Superior Region," 1880, p. 48. Proc. Boston Soc. Nat. History, 1881, pp. 266, 267; 1883, pp. 418, 419.

[2] Mon. U. S. Geol. Survey, vol. 1, Lake Bonneville, pp. 320-325.

[3] Am. Jour. Sci., Sept., 1888, vol. 36, p. 208. See also U. S. Geol. Survey Bull. No. 66.

the presence of the quartz is not determined by the chemical composition of the magma. He regards the quartz as primary and indigenous to the basalt, and advances a hypothesis to account for its crystallization in such a basic magma, attributing it chiefly to the action of superheated steam under considerable pressure. He calls attention also to several quartz-bearing basalts in the fortieth parallel collections,[1] and more especially to some found in Arizona and Colorado, as well as near Eureka, Nevada[2].

In connection with the Assos expedition in 1882, the writer collected specimens of quartz basalt upon the outskirts of the city of Mytilene, northwest of Smyrna. The lava is andesitic basalt, which contains numerous grains of quartz associated with brown glass and a border of pyroxene. Traces of phenocrystic quartz were observed in basalts of the Troad, near the plain of Troy, and in all cases there is no doubt as to the primary character of the quartz.

The investigations of Bleibtrau,[3] Lasaulx,[4] vom Rath, Zirkel,[5] Rosenbusch,[6] and especially of Lehmann,[7] have rendered the basalts of Jungfernberg, Petersberg, Oelberg, Niedermendig, and other places in the valley of the lower Rhine, celebrated for the quartz they contain.

The basalts contain inclusions which, according to Lehmann, have been fused. Quartz and a host of other minerals have been identified as crystallizing out of the fused mass chiefly in cavities. I have examined about a dozen thin sections of basalts from the localities named, including one from Gerolstein, and find rings of augite (Augitaugen) with or without grains of quartz in the center clearly marked in all of them. In nearly every respect the quartz I have seen closely resembles that in the lava at the Cinder Cone, and it is probable that much of it has the same history. It must be borne in mind that, according to Lehmann, there are two phases of quartz in many of the basalts in the lower Rhine Valley: (1) Quartz inclusions, which are small grains and more abundant than all other kinds of inclusions; each grain is corroded and surrounded by an envelope of augite; (2) well developed crystals of quartz (pyrogenous quartz), which crystallized out in cavities as a consequence of the fusion of siliceous (but not quartz) inclusions. Perhaps many of the simple grains of quartz which Dr. Lehmann, largely for theoretical reasons, regards as inclusions may be indigenous to the lava.

Rosenbusch mentions the occurrence of "Augitaugen" in the basalts of the Vogelgebirge. Lehmann writes that quartz grains occur in the

[1] Noted also by Zirkel (Geol. Explor. Fortieth Parallel, vol. 6, p. 251) and King (Geol. Explor. Fortieth Parallel, vol. 1, pp. 655 and 656), and Wadsworth (Bull. Comp. Zool., vol 5, No. 13, p. 286).

[2] Mr. Arnold Hague, in the Ann. Rept. of the Director U. S. Geol. Survey for 1881 and 1882, pp. 279 and 280, calls attention to the quartz grains in the Eureka basalt.

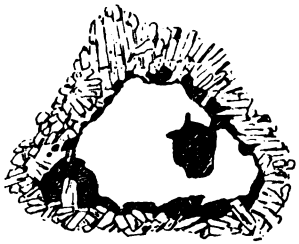
[3] Zeit. deutsch. geol. Gesellsch., 1883, vol. 35, p. 489.

[4] Elemente der Petrographie, p. 237.

[5] Lehrbuch der Petrographie, vol. 2, p. 285.

[6] Mikroskop. Physiog. der Min. und Gesteine, 2d edition, vol. 2.

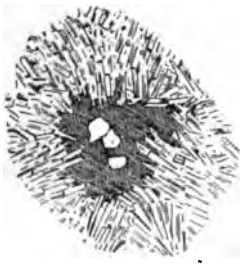
[7] *Verh. des* naturh. Vereins der preus. Rheinl. u Westfalens, 1877, p. 203.



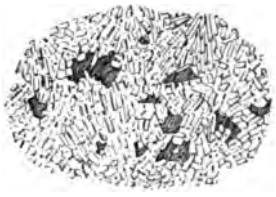
1

2

3



4



5

6

SECTIONS OF QUARTZ GRAINS AND SURROUNDING SHELLS OF GLASS AND AUGITE.

basalts of Bernsteingebirge bei Striegau, and Scrope[1] calls attention to them in a basalt of the Auvergne. In a specimen of basalt from Tannenbergthal,[2] Erzgebirge, obtained from Stürtz, of Bonn, corroded grains of quartz with pyroxenic rims occur.

Prof. J. W. Judd and the late deeply esteemed vom Rath both called my attention to the celebrated basalt at Detunata Siebenbürgen, and to Professor Judd I am greatly indebted for a fragment of the rock which he collected years ago. Professor Judd informs me that dihexahedral crystals of quartz occur in this rock, but by those who have visited the locality they are regarded as inclusions having been picked up from the dacite through which the basalt passed on its way to the surface.

Phenocrystic quartz, as we have seen, is widely distributed in regular basalts. It has been discovered also in closely related diabases, according to Rothpletz[1] and Stecker.[2]

In this country, Haworth[3] has just described an interesting example in Missouri, and Prof. B. K. Emerson has found a similar occurrence in the Connecticut Valley near Mount Holyoke, yet to be described. In diabasic rocks the pyroxene border may be inconspicuous or entirely absent. Notwithstanding the fact that occurrences of this sort have been described as anomalous and due to inclusions, there is much reason to believe, as Haworth has urged, that they are not only primary but indigenous.

I do not mean to assert that all of the grains of quartz in all of the rocks enumerated above are products of crystallization in the magma deep within the earth. It seems highly probable that such is not the case, but a careful consideration of the quartz basalt of the Snag Lake region leads me to suspect that much more of the quartz is indigenous than is generally supposed.

---

[1] Geology of the Extinct Volcanoes of Central France, p. 109.
[2] Neues Jahrbuch für Mineralogie Geologie u. Paläontologie, 1876, p. 400.
[1] Zeit. deutsch. geol. Gesellsch. 1878, vol. 30, pp. 554-556.
[2] Stecker: Min. u. petrog. Mittheil. v. G. Tschermak, Wien, vol. 9, p. 145.
[3] American Geologist, June and July, 1888, vol. 1, pp. 363 et seq.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 80

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

CORRELATION PAPERS

DEVONIAN AND CARBONIFEROUS

BY

HENRY SHALER WILLIAMS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

CONTENTS.

	Page.
Letter of transmittal by Mr. G. K. Gilbert	7
Outline of this paper	11
INTRODUCTION. The state of opinion at the beginning of the present century regarding the classification and naming of geologic formations	13
CHAPTER I. The history and development of opinion regarding the classification of rocks in the United States, from the time of William Maclure to the completion of the geological survey of the State of New York (1809–1843)	22
CHAPTER II. The general application of the nomenclature of the New York system as a standard of correlation in other parts of the United States (1840–1851)	58
CHAPTER III. Miscellaneous discussions regarding the correlation of Devonian and Carboniferous formations in the central part of the United States (1846–1887)	75
CHAPTER IV. The differentiation of the Carboniferous system	83
CHAPTER V. The Coal Measures or Pennsylvanian series: The development of its nomenclature and classification in the Appalachian Province (1836–1888).	108
CHAPTER VI. The conglomerates and Lower Carboniferous formations of the Appalachian Province	121
CHAPTER VII. The Chemung-Catskill problem: The history of the discussions concerning the correlation of the Chemung-Catskill formations in the northern part of the Appalachian Province	135
CHAPTER VIII. The Lower Carboniferous or Mississippian series: The development of the nomenclature and classification of the Lower Carboniferous formations of the Mississippian Province (1821–1874)	173
CHAPTER IX. The Waverly problem: The history of the discussion concerning the correlation of the Waverly, Marshall, Goniatite limestone, Kinderhook, and Choteau formations (1838–1888)	193
CHAPTER X. The Permian problem: Discussions relative to the correlation of the Permian in Kansas and Nebraska and other parts of the United States (1858–1886)	213
CHAPTER XI. Devonian and Carboniferous correlations in the Western and Northern Provinces of North America	226
CHAPTER XII. The Acadian Province: The correlations and classifications of the Upper Paleozoic formations in the Acadian Province	258

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOLOGIC CORRELATION,
Washington, D. C., March 15, 1891.

SIR: I have the honor to transmit herewith a memoir by Dr. Henry S. Williams on the Devonian and Carboniferous formations of North America, prepared for publication as a bulletin.

This memoir is the first of a series, and in order to show its relation to those which are to follow, I quote the following passage from the report of the Director for the fiscal year ending June 30, 1888:[1]

In order to develop the geological history of the United States as a consistent whole, it is necessary to correlate the various local elements. The events of one district—the succession of eruptions, sedimentary deposits, and erosions—must be connected with the synchronous events of other regions. It is especially important to determine the synchrony of deposits. So far as the outcrops of strata can be continuously traced, or can be observed at short intervals, correlation can be effected by the study of stratigraphy alone. The correlation of strata separated by wide intervals of discontinuity can be effected only through the study of their contained fossils. This is not always easy, and it is now generally recognized that it is possible only within restricted limits. As distance increases the refinement in detail of correlation diminishes.

Recent discussions in connection with the work of the International Congress of Geologists have shown that different students assign different limits to the possibilities of correlation, and give different weights to the various kinds of paleontologic evidence employed.

The study of the data and principles of correlation is thus seen to be a necessary part of the work of the Geological Survey, and by making the study at the present time it can offer a timely contribution to general geologic philosophy. It has therefore been determined to undertake the preparation of a series of essays summarizing existing knowledge bearing on the correlation of American strata. It is proposed to have a treatise prepared by a competent specialist on each of the following systems: The Quaternary, the Newer Tertiary, the Older Tertiary, the Cretaceous, the Jura-Trias, the Carboniferous, the Devonian, the Silurian, the Cambrian, the Eparchean, and the Archean.

Each essay will consider the several geographic provinces of the system it treats, the stratigraphic divisions that have been made in the several provinces, the extent to which these divisions can be correlated with one another, the degree of precision with which the upper and lower limits of the system can be correlated with the limits of the corresponding European system, and the extent to which the American subdivisions can be correlated with the European. It is proposed to treat sepa-

[1] *Ninth Annual Report of the U. S. Geological Survey*, p. 16.

rately the evidence from vertebrate fossils and the evidence from fossil plants as to all the systems in which they are found; and there will be prepared in connection with the work a thesaurus of North American stratigraphic terminology.

The work has been placed under the general charge of Mr. G. K. Gilbert, and a number of specialists to assist him have already been selected from the various divisions of the Survey.

Each of the systems indicated above was assigned to a paleontologist or a geologist for treatment, and several conferences were held for the purpose of developing a definite plan of work. Eventually the plan was formulated as follows, being incorparated in a circular letter addressed the Director to the several specialists chosen for the work in February, 1888:

PLAN FOR THE DISCUSSION OF AMERICAN GEOLOGIC SYSTEMS.

(1) It is proposed to prepare an essay on each of the following American geologic systems, namely: (1) Quaternary, (2) Plio-Miocene, (3) Oligo-Eocene, (4) Cretaceous, (5) Jura-Trias, (6) Permo-Carboniferous, (7) Devonian, (8) Silurian, (9) Cambrian, (10) x y z, (11) Archean.

The "Congress" committee of the American Association for the Advancement of Science at a recent meeting resolved (in effect) that "systems are determined primarily by fossils, secondarily by structure." This series of essays is planned on the assumption that for purposes of correlation the most important fossils are marine invertebrates. The evidence from vertebrates and that from plants will be discussed each by an appropriate specialist, but this arrangement does not preclude their consideration in the essays on individual systems.

(2) Each essay should show how the system of which it treats has been paleontologically and stratigraphically delimited in North America, and should recite and discuss the facts and principles on which such delimitation is based.

(3) Each essay should show into what series (major subdivisions) the system has been divided in various parts of North America, and on what facts and principles the division has been based. If these subdivisions are not uniform in all parts of the continent the various areas of exposure should be classified in provinces, and the essays should show whether and to what extent the series of the several provinces can be correlated with one another.

(4) Each essay should show whether and to what extent the subdivisions of the system in any or all of its American provinces can be correlated with the subdivisions of the system in Europe.

(5) Each essay should be prepared with the aid of a comprehensive review of the pertinent literature, so as to constitute a summary of the material at present available for the major taxonomy of the system.

(6) The names of systems in (1) are provisional. Each essay should consider the question of names for system and series.

The number of systems is likewise provisional, and it may eventually appear that those enumerated in (1) are not coordinate. It was necessary to prepare a scheme in order to apportion the work of assembling the facts, but after these have been assembled, their discussion may lead to an improved scheme. Provision will be made for such discussion after the series of essays has been prepared.

(7) The general purpose of the preparation of the series of essays is threefold: first, to exhibit in a summary way the present state of knowledge of North American geologic systems; second, to formulate the principles of geologic correlation and taxonomy; third, to set forth from the American standpoint the possibility, or the

impossibility, of using in all countries the same set of names for stratigraphic divisions smaller than systems.[1]

By comparing the list of geologic systems in this "plan" with the list in the passages cited from the report of the Director, it will be observed that there are slight discrepancies. The unsettled problems of nomenclature thus suggested were elaborately discussed by a conference of the geologists of the Survey held in January, 1889, for the purpose of establishing the conventions necessary to uniformity in the preparation of the sheets of the Geologic Atlas of the United States. By that conference it was determined that the stratigraphic units delineated on the sheets of the geologic atlas should be designated as formations, that no stratigraphic unit of a higher order should be recognized in the atlas, and that the only term of classification there employed should be the geologic "period."[2] The time-term "period" thus adopted for the geologic atlas has the same taxonomic rank as the stratigraphic term "system" employed in the "plan" for the instruction of the essayists and in the passage cited from the report of the Director. It was preferred by the geologists of the conference because it was believed that the major classification expressed by either term is essentially arbitrary and does not find in nature a universal expression, either physically through lithologic and structural differences, or biotically through the differentiation of faunas and floras. The chronologic term seemed to them freer than the stratigraphic from the implication that the classific units are natural and general rather than artificial or local.

The conference likewise indicated and defined eleven periods to be used in the classification of the formations represented in the atlas, and designated them as follows: (1) Pleistocene, (2) Neocene, (3) Eocene, (4) Cretaceous, (5) Jura-trias, (6) Carboniferous, (7) Devonian, (8) Silurian, (9) Cambrian, (10) Algonkian, (11) Archean.[1] These are the exact equivalents of the "systems" enumerated in the preceding quotations, but they differ somewhat as to name.

The conventions thus adopted for the work of the Geological Survey have modified and controlled the work of the division so far as they are applicable, and the substitution of "period" for "system" has changed the point of view of the essays in a manner conducive to their simplification and to their value as contributions to the subject of correlation.

Although the essayists, working under the same general instructions, have had before them the accomplishment of the same purposes with respect to the several groups of formations assigned them, no attempt has been made to mold their modes of treatment in a common form.

[1] This plan was published in the Tenth Annual Report of the Survey as part of a progress report of the work of the Division of Correlation (pp. 108–113). Further report of progress may be found in the Eleventh Annual Report, pp. 59–62.

[2] Tenth Annual Report U. S. Geological Survey, pp. 63–65.

[3] Ibid., pp. 65–66.

The present essay employs the historical method alike in the summarization of present knowledge and in the formulation of the principles of geologic correlation. It groups facts and opinions as to Carboniferous and Devonian formations about certain specific problems of correlation, and traces the history of the discussion of each problem. In connection with the historical summaries there is much incidental discussion of the principles of correlation, and they are afterward classified in a closing chapter. The author concludes, from the American standpoint, that in a universal classification of formations it is not practicable to employ classific units smaller than periods.

Very respectfully, your obedient servant,

G. K. GILBERT,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

OUTLINE OF THIS PAPER.

The following essay is a historical study of the classifications and nomenclatures of geological formations in America, made with the purpose of ascertaining how satisfactory correlations have been made and upon what principles they have been based. For this purpose the literature upon the whole Paleozoic for the first 40 years of the century has been reviewed, but for the period following the publication of the Final Reports on the Geology of the State of New York (1842–1844), the study has been confined to the literature of the Devonian and Carboniferous systems.

In the course of the historical development of the science, and as the geological surveys have extended over new territory, a number of specific problems have arisen for the solution of which it has been necessary to determine the relations between standard formations already named and classified and those newly discovered. In this essay the discussion of each of these problems has been followed out in detail, the various attempts at correlation have been noted, and the methods employed and the final results attained have been traced to the principles involved in their determination.

The following problems have been thus discussed:

(1) The general correlation of the Paleozoic formations of eastern North America with the corresponding formations of Europe.

(2) The determination of the parallelism between the upper Paleozoic formations of the Appalachian region and the rocks of the interior of the continent as far west as the Mississippi River.

(3) The correlation in the Northern Appalachian region of the various subdivisions of the Coal Measures and formations immediately underlying them.

(4) The problems connected with the correlation of the Chemung and Catskill groups, and with the correlation of the Waverly and Marshall groups.

(5) The elaboration of the Mississippian series, or "Subcarboniferous" formations of the Mississippi River basin.

(6) The Permian problem of Kansas and Nebraska.

(7) The correlation problems involved in classifying (*a*) the formations of the Acadian province, and (*b*) the formations of the Rocky Mountains and Western Plateau provinces.

In the discussion of these various problems several definite stages in the development of the principles of correlation have been recognized. At the opening of the century the Wernerian system of classification was generally adopted. In this classification the mineral characters of the formations were regarded as of fundamental importance, and constituted the chief criteria for their classification and correlation, and the order of deposition was supposed to be indicated by the actual and relative position of the present outcropping of the strata. The theory underlying this latter interpretation was, that the older rocks formed the core of the mountains; on the higher part and at an inclination were formed the next younger, and as the waters dried off the surface of the earth the successive rocks were deposited at lower and lower levels. The names "Primary," "Secondary," "Tertiary," and "Quaternary" preserve the memory of this theory, though the theory itself has given way to the more rational one of oscillation of the crust of the earth itself, with relative sta-

bility of the mean tide level of the ocean. The correlations of this period were defective, not so much on account of imperfect observation as on account of incorrect theories. "Red sandstone," "Mountain limestone," "Saliferous rocks," and "Grauwacke" were truly found in America, but they were not the correlatives of formations so named in Europe, because formations present no regularity in the order of sequence of their mineral characters. The perfecting of the New York system of Paleozoic rocks (published in 1842) marks practically the abandonment of the Wernerian school of opinion in America.

The second stage of development took definite shape in the New York system. Formations were considered as holding a fixed order of sequence, but differences in thickness or even in composition were to some extent allowed as compatible. Still, a general "parallelism of strata" was believed in, and in order to make the interpretation fit the facts, "gaps" and "intercalations" were assumed. The application of this principle of correlation is conspicuous in the various attempts at "parallelism" made in the period 1840–1860, and the method is most minutely carried out in the second Geological Survey of Pennsylvania, where the term "persistent parallelism of strata" is named and defined. Fossils were used in these correlations, but rather as arbitrary labels which were of value only when exact identity was recognized. This being rarely the case, fossils played only a secondary part. This principle did not reach satisfactory results, because stratigraphic order and stratification itself offer no intrinsic evidence of the age of the formation, and stratigraphic structure was found not to be uniformly persistent even for a few miles' extent.

In the first quarter of the century, an Englishman, William Smith, or "Strata Smith," as he was called, advanced the idea that strata could be identified by their fossils, and fossils have ever since been used with greater or less success in identifying formations; but when the fossils are not of the same but of kindred species, other considerations have been brought forward to establish the correlation. Within the last 20 years fossils have begun to be used on the principle that they contain in themselves intrinsic evidence of their relative age.

And this brings us to the third stage in the development of the methods of correlation in which fossils assume the chief rôle. Underlying these correlations are the following considerations: Geologic formations in their mineral and lithologic composition, their stratigraphic and structural characters, and as to their limitations are recognized as strictly local formations; hence the primary principle is that none of these characters can be relied upon for the correlation of formations of different localities. Secondly, fossils are recognized as remains of organisms which possess genetic relationship; and the specific and varietal characters of the organisms are believed to be indications of these affinities; and with evolution in time and modification coordinate with changed condition of environment, the organisms are believed to be extremely sensitive indicators of time relations. Thus the minute and exhaustive comparative study of fossils in their stratigraphic and geographic relations is now proving to be not only the best but the only reliable guide to correlation of geologic formations.

The conclusions reached from this historical study confirm the belief that the description and nomenclature of structural formations should be quite independent of their correlations, and that precision in correlation must be based upon mature and exhaustive paleontologic study, that the time scale must be made independently of the structure scale, and that the time scale of correlation is based fundamentally upon biologic data.

The investigation leads to the further conclusions that as nomenclature finds its basis in some structural characters of the [illegible] *nomenclature* for formations is inapplicable, since the intrinsic characters of formations are local and have nothing to do with their geologic position; and that [illegible] *classification* can be looked for only through an exhaustive biologic study of the fossils, and is inapplicable to geological structure, stratigraphy, or formation.

THE DEVONIAN AND CARBONIFEROUS FORMATIONS OF NORTH AMERICA.

By Henry S. Williams.

INTRODUCTION.

THE STATE OF OPINION AT THE BEGINNING OF THE PRESENT CENTURY REGARDING THE CLASSIFICATION AND NAMING OF GEOLOGIC FORMATIONS.

THE STATE OF GEOLOGICAL OPINION PRIOR TO 1835.

Upon reviewing the works of geologists written in the early part of this century, we find a very well marked school of opinion pervading all the works of English and American geologists, who published their works prior to the year 1835. A gradual change was taking place 10 years before this, but it was not until after 1835 and about 1840 that the new school of opinion, as expressed in modern classification of geological deposits, became generally adopted.

The prominent English text-books upon geology which appeared prior to that date are those of Maclure, 1817; Maculloch, 1821; Eaton's "Index," 1820; "Erie Canal Rocks," 1824; Conybeare and Phillips, 1822; Lyell's "Principles," 1830; De la Bêche, first edition, 1831.

All these books are based upon the general principle for the propagation of which, if not for the entire origination of the idea, Werner is distinguished. This idea which characterized the Wernerian school consisted fundamentally in the attempt to classify geologic deposits by the minerals which they contained and their petrographic characters.

Abraham Gottlob Werner (1750–1817), who has been called the father of German geology, was undoubtedly the founder of the classification of rocks into formations arranged in stratigraphic order.

Although his "theory of formations" has been superseded by other theories, the proposition that the crust of the earth is divisible into formations and that these formations have a regular order of sequence in relation to one another is at the very foundation of modern geology.

Werner was an enthusiastic teacher, but he wrote little, and we are obliged to look to the writings of his pupils and their followers for an exposition of the views which formed the basis of geological science at the beginning *of the XIX century.*

In the Edinburgh Encyclopædia[1] there is an exposition of his views which will serve our present purpose.

The author divided the science of mineralogy into two divisions, geognosy and oryctognosy. He said:

> Geology, according to Werner, comprehends not only geognosy but also geography, hydrography, meteorology, and geogony. Geognosy makes us acquainted with the structure, relative position, materials, and mode of formation of the mineral masses of which the crust of the earth is composed.

WERNER'S SYSTEM.

In 1740 De Maillet maintained that the globe was composed of strata successively deposited one over another, by the sea, which gradually retired and uncovered the present continents. This view was adopted by Linnæus. Buffon accepted it also, in part, so far as regarding superficial strata as the deposition from water. It played a conspicuous part in Werner's system.

Werner had several pupils, of whom some of the more prominent are Mohs, Charpentier, Buch, Raumer, Freisleben, Humboldt, Steppen, Engelhart, Esmarck, D'Andrada, Brocchi, De la Rio. In the article before us we find Werner's system discussed under the following heads: "Werner on the structure of the crust of the globe." Then follow the subdivisions:

1. Original extent of the formations.
2. Their present extent and continuity.
3. Position and direction of strata in relation to fundamental rocks.
4. Position and direction of strata themselves.
5. Relation of the outgoings [outcrop] of the strata to the exterior of mountains.

Under the first head, "the original extent of formation," Werner distinguished as "universal formations" those that extend around the whole globe (not, however, without interruption), and constitute by far the greater mass of the crust of the earth. Almost all the Primitive, Transition, and Secondary formations are "universal depositions." Of these the following are named: "Granite, Gneiss, Porphyry, Limestone." "Partial formations," of which sandstones, limestones, shales, etc., are examples, were deposited only in particular places, and were due to lake or flood sediments. The author wrote:

> The spheroidal figure of the earth, its crystalline and stratified structure, and its numerous petrifactions are proofs of its original fluidity. The fluidity, according to Werner, was aqueous, and he conjectures that the various rocks were originally suspended or dissolved in water, and gradually deposited from it.[2]

Two grand epochs are recognized in his system, first, "the Primitive, containing no fossils or organic remains, always below the other rocks, and wholly of chemical origin." "Second, the Secondary: these rocks were formed posterior to the creation of organized beings." The rocks

[1] The Edinburgh Encyclopædia, conducted by David Brewster, LL. D., F. R. S. 1812–1831. Article "*Mineralogy*," prepared by Prof. Robert Jameson, D. D., F. R. S., L., and E., professor of natural history. *Edinburgh. First American edition*, 1832, vol. XIII.

[2] *Op. cit., p. 437.*

of this group which resemble the first group, but contain fossils, are called "Transition" by Werner, and "Intermediate" by other geologists. The Secondary are called "Floetz."

In addition to these two grand epochs, there were recognized by some geologists,

(3) The Tertiary, including the upper part of the Secondary class of Werner, which is distinguished as containing the remains of quadrupeds;

(4) An Alluvial class, consisting of gravel, sand, clay, marls, recognized by its resting upon the previously mentioned class; and

(5) The Volcanic class, the rocks of which were undoubtedly produced by fire.

In general, Werner believed all rocks were formed from one and the same solution by deposition, either chemical or mechanical. These "depositions" were made at various heights determined by the gradual departure of the water as it evaporated or sank away into cavities in the earth. But, to account for the formation of the "Secondary trap" and certain "Primitive porphyries," new inundations were assumed to have taken place.[1] In his system there were series of formations, and each series was denominated a "suite;" thus, there were eight of these suites, called—

1. Limestone formation suite.
2. Slate formation suite.
3. Trap formation suite.
4. Porphyry formation suite.
5. Gypsum formation suite.
6. Salt formation suite.
7. Coal formation suite.
8. Serpentine formation suite.

Thus, "the limestone formation suite" consists of—

1. White granular limestone in the Primitive class (with large, granular, distinct concretions).
2. Variegated limestone in the Transition rocks, having "less translucidity," and containing the first traces of petrifactions.
3. The gray Floetz limestone, scarcely translucent on edges, and full of petrifactions, and found in the Floetz or Secondary rocks.
4. Chalk.
5. Limestones and marls of the Paris Basin.
6. Calcareous tuff.

In these series, extending from the earliest to the latest period, there is a gradual disappearance of the crystalline, and a gradual increase of the earthy aspect, "corresponding with the relative age of the different members of the series, and the state of the solvent from which they were precipitated, and all serving as proofs of the immensely great but gradual alteration of the state of the universal waters." "Quietness of the water" was the characteristic at first, and as the

[1] *Op. cit.*, p. 136.

waters shallowed they were more disturbed, and the resulting rocks were less crystalline and more earthy; and, lastly, the earthy limestones as a result of exposure of the rocks to erosion by withdrawal of the waters.

Another point conspicuous in his theory is that regarding the actual position of the rocks as indicative of the age when they were formed. In describing each of these formation series we find the following sentence, "with sinking levels of the outgoings of the newer and newer strata."

The following exhibits Jameson's idea of the classification, which is apparently an amplification of the scheme taught by Werner.

CLASSES OF ROCKS.

CLASS I. *Primitive Rocks.*—Urgebirge of Werner; Terrains primitifs of Daubuisson.

Those formed antecedent to that of the creation of organic beings. Chemical formation, no fossils, under the Floetz or Transition.

The rocks of this class are—

1. Granite, with syenite, protogene topaz rock.
2. Gneiss, and varieties of white stone.
3. Mica slate, and varieties of talc slate.
4. Clay slate, Thonschiefer, with alum slate, flinty slate, etc.
5. Granular limestone, and primitive gypsum.
6. Primitive trap.
7. Serpentine and euphotide.
8. Porphyry.
9. Quartz rock.

CLASS II. *Transition Rocks.*—Ueberganggebirge of Werner.

Contains fossils, is less crystalline than the Primitive, and interposed between the Primitive and Secondary.

The rocks are—

1. Grauwacke, Werner; Psammite of Brongniart.
2. Transition limestone.
3. Granite and porphyry.
4. Gneiss, mica slate, etc.
5. Serpentine,
6. Quartz rock.
7. Red sandstone.
8. Transition trap.
9. Gypsum.

Class III. *Secondary or Floetz rocks.*—Floetzgebirge of Werner; Secondary or Floetz rock of Jameson; Terrain secondaire of Daubuisson. It rests on Transition or Primitive, is less crystalline, has many fossils.

The principal Secondary rocks are—

1. Sandstone.
2. Limestone.
3. Gypsum.
4. *Trap rock.*

1. Sandstone: Conglomerate, Breccia, including—

First or Red sandstone, with the coal formation, or
Old Red sandstone of Jameson,
Aelter rother Sandstein of Werner.
Rothe-todte-liegende of German miners,
Grès ancien of Daubuisson.

The coal formation is the "coal measures" or "coal fields" of the English miners, the "Steinkohlengebirge" of Werner, "Terrain houiller" of Daubuisson, "Terrain à charbon de terre" of older French writers.

It includes coal, slate, sandstone, quartz rock, clay, trap, graphite. Coal is either black coal or "glance" or "blind." The coal formation rests on the Mountain limestone or Red sandstone, and underlies the Magnesian limestone.

The *second sandstone* is the New Red or Variegated sandstone, the "bunter Sandstein" of Werner, "Red Ground" of English geologists, "New Red" of Buckland, "New Red or Variegated sandstone" of Jameson. The second formation of "grès" and "grès avec argil," and "grès bigarre." It rests upon the second or Magnesian limestone.

The *third sandstone* formation, "Green Sand" of English geologists, "third sandstone formation" of Jameson and Daubuisson, "Quadersandstein" of Werner. It rests upon the upper Oolite, and is covered by the chalk.

The *fourth sandstone* formation is associated with the rocks that rest upon the chalk.

2. Secondary or Floetz limestone: There are five of these, called first, second, third, fourth, and fifth secondary limestones.

The *first secondary limestone* of Jameson is the "Alpine and Jura limestone" of the Germans and some French authors, and the "Mountain limestone" of English geologists. In regular succession it comes after the Old Red sandstone.

The *second secondary limestone* of Jameson is probably the "Erster Floetz Kalkstein" of Werner, the "Magnesian limestone" of English authors, and rests upon the coal formation.

The *third secondary limestone* of Jameson is the "Muschel Kalkstein" of Werner, "Oolite," of Buckland, "Lias and Oolite," of others.

The *fourth secondary limestone* is the "Chalk," the "Kreidegebirge" of Werner, and rests upon the third sandstone.

The *fifth secondary limestone.* (See the "Paris formation.")

3. The Secondary Gypsum of Jameson, the "Floetz Gyps" of Werner. This included the first and second gypsum, also the "Steinsalzgebirge," of Werner. In this second class were also included the formations above chalk, or the Paris formation, the "Terrain Tertiare" of Daubuisson, which includes seven different beds.

CLASS IV. *Alluvial rocks.*

Up to the end of the first quarter of the century very little knowledge was possessed of the characteristic fossils contained in geological de-

posits. William Smith, as all geologists know, early in the century recognized the importance of fossils in identifying geological deposits, and as early as 1812 a map of England and Wales was prepared by him with the order of the geological deposits marked upon it, and it was known, by William Smith, at least, that the several strata were characterized by different organisms. The order of these deposits was known by him, and a table was drawn up in 1799, some improvements were made in his map and in his table in 1815 and 1816, and in 1815 a small treatise was published by Smith, entitled "A Geological Table of British Organized Fossils," which identified the course and continuity of the strata.

It will thus be seen that in the earliest decade of the century there was one man, at least, who recognized the importance of fossils in determining and correlating geological strata. The methods of Smith were applied, however, no lower than the Carboniferous system, and it was not until later that they were adopted as a general principle for the classification and systematization of the whole geologic column.

Although fossils were recognized as important, they were so poorly understood, and so few individuals studying geology had any accurate knowledge even of their generic characters, that they were of very slight service in correlating strata.

Mineral characters, therefore, played the principal part in all the classifications, correlations, and even nomenclatures of the geologists of the first quarter of this century.

Much confusion is found, also, in the attempts to generalize, on account of ignorance of the true means of correlating the strata that cropped out in different regions. The early names used indicate the principles of these classifications, such as "Granular limestones," "Argillite," "Grauwacke," "Old Red sandstone," "Oolite," "Cretaceous," "Magnesian limestones"; and a great many others could be enumerated. These, it will be seen, are all names indicating the usage of mineral characters for the distinction of the strata, independent of their locality and independent of their order of sequence or position in a vertical scale.

In order to change this system, it was necessary that a careful study of fossils be made, that their biological relations be clearly understood, and that their characters be geographically and geologically known. The classification of the geological deposits for England was fairly well understood for the Mesozoic and higher strata as early as 1822, but the lower strata, the Paleozoic series, as we now understand it, were not well understood prior to the works of Murchison and Sedgwick and their associates. Murchison's "Silurian system" was not published till 1839, and the classification of the Paleozoic series, although studied by English and Americans between 1830 and 1840, can not be regarded as having been fully understood by geologists until about the year 1840.

A glance at the general system of classification in the early text books

will give the best idea of the state of opinion in this first period of geological science. The rocks were classified at the beginning of the century by the Wernerian school into Primary and Secondary rocks; the idea contained in this distinction was, for the first, those rocks which were originally deposited from chemical solution and by evaporation from the ocean waters, and the Secondary were those which were produced by water erosion and reshaping of the Primary rocks, and deposition of the sediments above them. In the Secondary series fossils were observed, but the Primary series was supposed to have been laid down before the existence of organisms upon the earth. As observations accumulated, the rocks called Primary were found to include some which are now placed in the Paleozoic series. The name Transition came into use as a designation for the rocks, which were known to be stratified and occasionally to contain fossils, occupying a position between the original Primary and Secondary formations. The Germans applied the name "Grauwacke" to this Transition series, and we find in Eaton's classification, as presented in his "Index to the Geology of the Northern States," his "Erie Canal rocks," and his other papers, the use of the term "Grauwacke" in a sense which is different from that originally applied, but one necessitated by the discovery of the same kind of rocks at undoubtedly different horizons. The "Grauwacke" of Eaton was spoken of as "First," "Second," and "Third Grauwacke," etc., and we find him identifying the great mass of the rocks of western New York as belonging to the "Third Grauwacke," which he placed in the Secondary class. This "Third Grauwacke" is placed above the Carboniferous, and also above the "Saliferous rocks," a name which he used to represent the English Saliferous group, but which he identified with the Onondaga Salt group or Salina of the New York system. This was placed above the Conglomerates in the order of sequence because the "Millstone Grit," which they were supposed to represent in the English series, was below the New Red sandstone.

The imperfection in the methods of correlation of this time is well illustrated by Eaton's identification of the "Old Red sandstone" in New York.

In "Erie Canal rocks," 1824, "Old Red sandstone" is placed at the top of the "Transition class." It included the "Red sandstone of the Connecticut River," and the "Red sandstone of the Catskill Mountains," and in 1820 he reported the "Old Red sandstone" as outcropping in the Niagara gorge.

This example shows that the color and composition were the basis of correlation, and that the belief that the order or sequence of formations must be the same in New York as in Great Britain led to the erroneous classification.

This confusion is due not so much to poor observation, which Eaton can not be charged with, as to erroneous theories which were common to geologists in his time. The recognition of the position of the Car-

boniferous in the Paleozoic, and its relation to "Old Red sandstone" and "New Red sandstone," are two distinct issues. Stratigraphically, the relation of the Coal Measures and its associated Carboniferous limestones and Millstone Grit with the Old Red sandstone below and the New Red sandstone above, was well established, but the division line, which separates our Paleozoic from Mesozoic, was not drawn until the fossils had been carefully studied.

Originally, and beginning with the works of Bakewell and De la Beche, and Conybeare and Phillips, above mentioned, the Carboniferous Coal Measures were associated with the Secondary rocks of Werner, and we find in the latter work,[1] which, it will be noticed, was published in 1822, that the "Old Red sandstone" in part is also included in what is called the "Medial or Carboniferous order." This was the first step toward the modern classification into Paleozoic and Mesozoic. By the majority of geologists for several years later than 1822, the Old Red sandstone and the Carboniferous were included in the Secondary, and the rocks below[2] were placed in the Transition or Grauwacke of the older classifications.

It was John Phillips[3] who first clearly conceived the importance of associating the Carboniferous, the Devonian, and the Magnesian limestones together, and separating them from the rest of the New Red formation, to form the upper part of the Paleozoic strata. This brought the demarkation between the ancient (Paleozoic) fauna and the middle (Mesozoic) fauna at the top of the Permian, or, in England, at the top of the Magnesian limestones; and the distinction was based purely upon the study of the contained fossils. This was first suggested in the articles in the Penny Encyclopedia, in 1840 and 1841, entitled "Paleozoic Rocks" and "Saliferous system," and the statement that Phillips is responsible for so extending the Paleozoic is given in his "Paleozoic Fossils."[4] The term "Paleozoic" was suggested by Sedgwick to take the place of "Protozoic," the term which Murchison applied to the rocks described in his "Silurian system," and which were regarded as belonging to the Transition strata of the Wernerians.

Thus it will be seen that the grand distinction between Mesozoic and Paleozoic, as now understood, was entirely determined by the fossils.

The study of the Devonian rocks, and the determination of their position by Lonsdale in 1837, furnish another example of the application of paleontology in perfecting classification. The rocks themselves, their stratigraphy, their relations to other rocks, had been carefully studied by Murchison and De la Beche, and by numerous others in a more irregular way, prior to 1838, but the identification of their fossil contents by Lonsdale, and their comparison with the fossils of other formations, made it possible for him to assert positively that the posi-

[1] Conybeare and Phillips's Geology, etc.

[2] The Silurian, Cambrian, and, as we see in De la Beche, the Devonian systems.

[3] Author of "Paleozoic Fossils of Cornwall, Devon, and West Somerset," published in 1841.

[4] *Page 180.*

tion of the Devonian rocks chronologically, in the geological series, is between the Silurian system of Murchison, and the Carboniferous system of Conybeare, heretofore regarded as of the Secondary strata of Werner.

The demarkation of the Paleozoic by its fossils which we owe to Phillips and the determination of the intermediate position of the Devonian system by Lonsdale were two conspicuous examples of the inestimable value of fossils for geologic correlation. Heretofore the methods of the Wernerian school were dominant in all geologic classifications and correlations. Afterward in English and American geology paleontology became the indispensible ally of stratigraphic geology.

CHAPTER I.

THE HISTORY AND DEVELOPMENT OF OPINIONS REGARDING THE CLASSIFICATION OF ROCKS IN THE UNITED STATES FROM THE TIME OF WILLIAM MACLURE TO THE COMPLETION OF THE GEOLOGICAL SURVEY OF THE STATE OF NEW YORK, 1809-1843.

An article appeared in the Trans. Am. Phil. Soc., in the year 1809,[1] which is among the earliest careful expositions of the systematic arrangement of the rocks of North America, if not the very earliest.[2]

The classification adopted by Maclure is the Wernerian, and he defends the usage of this system by the following arguments[3]: "First, because it is the most perfect and extensive in its general outlines; and secondly, the nature and relative situation of the minerals in the United States, whilst they are certainly the most extensive of any field yet examined, may perhaps be found to be the most correct elucidation of the general exactitude of that theory as respects the relative position of the different series of rocks."

The following is the nomenclature adopted:[4]

CLASS 1. *Primitive rocks.*—(1) Granite, (2) Gneiss, (3) Mica slate, (4) Clay slate, (5) Primitive limestone, (6) Primitive trap, (7) Serpentine, (8) Porphyry (9) Syenite, (10) Topaz rock, (11) Quartz rock, (12) Primitive flinty slate, (13) Primitive gypsum, (14) White stone.

CLASS 2. *Transition rocks.*—(1) Transition limestone, (2) Transition trap, (3) Greywacke, (4) Transition flinty slate, (5) Transition gypsum.

CLASS 3. *Floetz or Secondary rocks.*—(1) Old Red sandstone or first sandstone formation, (2) First or oldest Floetz limestone, (3) First or oldest Floetz Gypsum, (4) Second or Variegated sandstone, (5) Second Floetz gypsum, (6) Second Floetz limestone, (7) Third Floetz sandstone, (8) Rock Salt formation, (9) Chalk formation, (10) Floetz Trap formation, (11) Independent Coal formation, (12) Newest Floetz Trap formation.

CLASS 4. *Alluvial rocks.*—(1) Peat, (2) Sand and gravel, (3) Loam, (4) Bog iron ore, (5) Nagel fluh, (6) Calc tuff, (7) Calc sinter.

It is singular to notice how persistently this original error of placing the "Coal formation" high up in the "Secondary" was perpetuated by later geologists. So, too, the position of the "Rock Salt formation," which was in the Mesozoic in England, was erroneously regarded, when

[1] Vol. 6, pp. 411-428.

[2] The article is entitled "Observations on the geology of the United States, explanatory of a geological map, by William Maclure, read January 20, 1809." For students of early maps, it is well to remember this map of Maclure's in the Transactions.

[3] *Op. cit., pp. 411, 412.*

[4] *Ibid., p. 412.*

discovered in New York and other places, as a central one in the "Floetz rocks."

The position of the "Independent Coal formation" is defined by Maclure as extending "from the head waters of the Ohio, with some interruption, all the way to the waters of the Tombigbee."[1]

This "Coal formation," as mentioned above, is placed in the upper part of the "Floetz," and is said to lie on "immense beds of Secondary limestone, intercepted in some places by extensive tracts of sandstone and other Secondary aggregates."

Maclure was familiar with the theoretical classification of Werner, and it is instructive to us, seeking a universal classification for the rock formations of the earth, to observe that the first geologist of America, in 1809, found the formations of America "the most correct elucidation of the general exactitude" of this German system. Perhaps American geologists are not at present in danger of imitating any foreign system with such reverence, but the attempt to harmonize or coordinate the classifications across the ocean leads to the same imperfect science, unless strict and even severe adherence to the facts be insisted upon.

In 1818 Elias Cornelius, in a paper on the geology, mineralogy, etc., of parts of Tennessee, Virginia, and Alabama and Mississippi Territories, defined two limestones which he distinguished as the "inclined strata" and the "horizontal strata," reminding us here of the Wernerian "Floetz" formation. His "inclined strata" were observed along the route of his travels over the Blue Ridge and the Cumberland Mountains, and all of the five ranges of the Alleghany Mountains. They were usually called gray limestones, sometimes reddish, as at Knoxville. The second, or "horizontal strata," of bluish color, he observed from the Cumberland Mountains for 200 miles southwestward. The editor explains in a note that the "highly inclined limestone" is the *Transition* of Werner; the "flat strata" belong to the *Secondary*.

John Grammar, jr., gave an account of coal mines in the vicinity of Richmond, in Chesterfield County, and noticed that the coal rests upon granite, is inclined 45° to the horizon, and has a thickness from 25 to 50 feet, thinning out southward; but he did not describe its geological horizon.[2]

In an article by John H. Kain, we find a reference to coal worked at Knoxville, Tennessee.

Daniel Drake published "A geological account of the valley of the Ohio."[3]

This is in a letter to Joseph Correa de Serra, and it presents his views in regard to the surface rocks and conditions, and some of the basement rocks are also referred to in the article, but the nomenclature for these is entirely Wernerian, as "Floetz," "Secondary," "Geest," etc.

---

[1] Trans. Am. Phil. Soc., vol. 6, p. 425.

[2] This is the first notice we see of the Mesozoic coal formations of this region.

[3] Trans. *of the Am. Phil. Soc., vol. 2,* new series, pp. 124–139.

In 1819 the American Geological Society was formed.[1] It was incorporated by the State of Connecticut and provisionally located in New Haven, and the first meeting was held in the philosophical room of Yale College, New Haven.

The Geological Society continued in existence for several years and gradually came to an end.[2]

It is evident from the honor bestowed upon William Maclure that in the first quarter of the century he was regarded as the most learned American geologist. In 1819, when the American Geological Society was started in New Haven, he was elected its first president. In a note at the foot of page 360, volume II, of the Silliman Journal, where a donation from him to the American Geological Society is referred to, he is described as a gentlemen who "has, in person, examined the geology of almost every portion of Europe as well as of the civilized portions of America. He has visited several countries repeatedly, and has inspected most of the interesting localities of minerals in Europe and America."

When we remember how few of the present facilities for travel and communication with foreign lands were existent in 1820, when this was written, some idea can be formed of the great influence such a man must have exerted over the opinions of American geologists.

W. B. Stilson, in a sketch of the geology and mineralogy of a part of the State of Indiana, briefly described the geological formations of the State, and referred them to the "secondary rocks." This was a correct correlation following Maclure's classification; the mistake, as before noted, was in the standard scale.

In 1820 Prof. Amos Eaton published "An Index to the Geology of the Northern States."[3] The observations recorded in his book are almost entirely the result of his own personal experience. He writes in the preface, page vi: "With respect to the theoretical part, as far as I have given in to any theory it is to that of Werner, with the improvements of Cuvier and Bakewell."

He recognized eighteen strata in order from the bottom upward, which he grouped into five classes. These were as follows:

	Strata.
I. Primitive class	1. Granite.
	2. Gneiss.
	3. Hornblende rock.
	4. Mica slate.
	5. Talcose rock.
	6. Granular limestone.

[1] Am. Jour. Sci., vol. 2, page 139.

[2] Prof. Dana informs me by letter, October 30, 1888, that by consultation of the records of the society in Yale College library he ascertained that the last meeting of the society was held in 1826, and the last member, E. Leffingwell, died in New Haven during the year 1888. Isaac Lea was a member of the society, and when he died there was but one member of the society still living. In the early numbers of the American Journal of Science frequent references are made to the reception of books and specimens by the society.

[3] Second edition, 286 pages, 12mo, Troy, New York.

II. Transition class	7. Argillite. 8. Metalliferous limestone. 9. Graywacke. 10. Red Sandstone (including those of "Catskill Mountains, Oswego River, Niagara River, and Connecticut River").
III. Secondary class	11. Breccia. 12. Compact limestone. 13. Gypsum (Manlius, Onondaga, Madison, etc.). 14. Secondary sandstone.
IV. Superincumbent class	15. Basalt. 16. Greenstone trap.
V. Alluvial class	17. Geest. 18. Alluvion.

This follows the general system of Bakewell, who was a disciple of Werner; but the individual strata are partly peculiar to his own system, although distributed in the several classes of the Wernerian classification.

In 1821 we find a notice of the occurrence of "blind coal" on the bank of the Arkansas, 500 miles from its mouth, "equal to the best Kilkenny coal;" this by L. Bringier.

In a letter to Silliman (the editor of the American Journal), dated 1820, Brongniart writes about fossils in a way to show how they were then used, and to what a slight extent they were of value in the interpretation of geologic strata. He says[1] in regard to Trilobites: "I learned from these specimens, and from some others which I received in different ways, that Trilobites existed in America as well as in Europe; that the animals differed very little (if, indeed, they constantly differed at all) from those of Europe, and that they are, in both cases, found in the *Schists phyllades*, or in the transition limestone, or, at least, in those which are very ancient."

Ebenezer Granger noticed some vegetable impressions from the coal formation of Zanesville, Ohio, and recognized them as *Lepidodendra* and *Calamites*, but did not further identify them.

Thomas Nuttall[2], of Philadelphia, records some "Observations on the Geological Structure of the Valley of the Mississippi." He gives an account of the probable limits and character of the "secondary formations" in the Mississippi Valley. He compares the calcareous platform of the Mississippi (as seen in the plains of Ohio, Michigan, Indiana, Illinois, Kentucky, western Tennessee, and Missouri) to the plains of the Tartarian district, traversed by the Kuban, as described by Pallas and Clarke, and he states that he thinks he meets in these calcareous deposits "almost every fossil described and figured in Martin's Petrifacta Derbiensia."

Although he makes no allusion to specific identification, this is a clear recognition of the "Carboniferous rocks" in these limestones of the interior.

In 1822 Zachariah Cist gave an account of the Lehigh and Schuyl-

[1] Am. Jour. Sci., vol. 3, p. 226.

[2] Jour. of the Acad. of Sci. of Philadelphia, 1821, vol. 2, pp. 14–65.

kill coal mines in the neighborhood of Wilkes-Barre, Pennsylvania, which were then being worked to the extent of 1,500 tons annually sent to market.

In 1823[1] Ami Borré discussed "European Geology, with remarks on the prevailing geological arrangements." The nomenclature is mainly Wernerian; such terms as "Encrinal limestone," "Old Red sandstone," and "Coal Formation" are associated with "Grauwacke," "Floetz," and "Red Ground," and in the next volume,[2] Conybeare and Phillips's Geology is reviewed.[3] In the review the supposition is made that our salt and gypsum beds may belong to the "original marl" of the authors, and doubt is expressed as to the Connecticut Old Red sandstone being really the equivalent of the "red marl."[4]

The "Rhode Island anthracite" is referred to "transition slates," graywacke slate.[5] It is distinctly stated[6] that in this country no distinction had theretofore been made between "rothe todte liegende" and the English "Old Red sandstone," and the argument is set forth that since the red sandstone in Connecticut lies below the coal measures therefore the "rothe todte" is not uniformly above the coal, as it is claimed to be by the authors, the Connecticut sandstone having been recognized by its fossils as equivalent to the "rothe todte."

Again, in this same year, Prof. Edward Hitchcock gave a considerable account of "the Geology, Mineralogy, and Scenery of the Connecticut River." He recognized the sandstone along the Connecticut River as unmistakably the "Old Red sandstone" of the English authors.[7]

Also, he referred to the occurrence of the "coal formations" along the river, at Chatham, at Middletown, and at Berlin.[8] The occurrence of fish in these coal beds at Westfield and Sunderland is mentioned on page 76, where one of them is referred to the genus *Palethrissum*. In the next volume[9] the "Rhode Island coal formation" is said to be older than that of Connecticut, and the supposition is made that they are both "transition." Hitchcock in his classification evidently followed Conybeare and Phillips's Geology, and from a foot-note[10] it is evident that he regarded the red sandstone to be the same with the "rothe todte liegende," "which," he says, "lies immediately below the bituminous marl formation of Germany, and below the coal formation in England." He quoted Conybeare as considering them distinct, and ventured the supposition that the "red sandstones of the Connecticut Valley" are not "Old Red" but "rothe todte," although he still considered the sandstones west of the Connecticut River as true Old Red sandstone.

This confusion in regard to the determination of our red sands was not altogether due to faulty stratigraphic observation on the part of

[1] Am. Jour. Sci., vol. 6, pp. 188–192.
[2] Ibid., vol. 7, pp. 203–240.
[3] This was published in 1832.
[4] Red marl of Conybeare and Phillips is in the *Triassic*.
[5] *Am. Jour. Sci. vol. 7, p. 224.*
[6] Ibid., p. 230.
[7] Ibid., vol. 6, p. 39.
[8] See Ibid., pp. 41, 44.
[9] Ibid., vol. 7, p. 28.
[10] Ibid., p. 27.

our geologists, but to confusion in their identification of them with the red sandstones described in the English books. The English geologists themselves were not yet united in distinguishing the red sandstones in their own country, and here, too, the trouble was more due to an attempt at correlating them with the red sandstones of the European Triassic than a failure to understand their difference in England. It was not until considerably later that our geologists clearly distinguished and placed in their proper geological horizon the Triassic sandstones of the Connecticut Valley and southward along the Atlantic border, and the several Paleozoic red sandstones now known as Potsdam, Medina, and Catskill red sandstones.

The year 1824 is noticeable in the progress of American Geology by the publication of Amos Eaton's work on the Erie Canal rocks.[1]

Part 1 contains a description of the rock formations, together with a geological profile extending from the Atlantic to Lake Erie. The classification is substantially that adopted in his text-book, though somewhat modified. In the place of the sixteen strata he has twenty-five, distributed in the four classes, Primitive, Transition, Secondary, and Superincumbent. His favorite system in naming rocks is recognized in the new names which he proposes in his classification. These are after the pattern of "the metalliferous lime rock," that is, the Latin termination meaning "to bear," added to the name of the mineral, and applied to the rock. Such terms are "saliferous rock," "ferriferous slate," "geodiferous slate," "lime rock," etc. A few of these terms are still preserved in our nomenclature, but where they are used they are confusing, and the objection to them is the objection to all of the names of the Wernerian school, that they are attempts to define rock strata by their mineral and physical characters, under the supposition that these characters were traceable in other than the locality where the original stratum was described. Stratigraphic geology was impeded by the attempts to perpetuate this method of classification, and we are scarcely yet entirely free from the influence of this Wernerian school.

A review of this book is given in the eighth volume of the American Journal of Science.[2]

Objection is there taken to the "unnecessary innovations in geological nomenclature," or to "any deviation from the present highly improved state of the science on the eastern continent, unless it is where new facts and discoveries imperiously demand such a course." This is evidently a rap at Prof. Eaton's criticism of Phillips and Conybeare's Geology, published in the same volume of the American Journal of Science[3] a few months before.

[1] A Geological and Agricultural Survey of the District adjoining the Erie Canal, by Amos Eaton, 163 pages and a plate, Albany, New York, taken under the direction of the Hon. Stephen Van Rensselaer.

[2] Pp. 358-362.

[3] Pp. 261-263.

Eaton's article is entitled "Ought American geologists to adopt the changes in the science proposed by Phillips and Conybeare?" He protests against accepting such a radical change in classification as Phillips and Conybeare propose, which is practically a defense of the older Wernerian classification, while Conybeare and Phillips, conceding the importance of defining the various formations by their chemical and external characters and mineral contents, distinctly recognized also the importance of the organic remains as a means of determining and characterizing each individual geological formation, thus following directly in the steps of William Smith and Cuvier.

In 1824, in volume 1 of the second series of Transactions of the Geological Society, is an article by J. L. Bigsby, entitled "Notes on the Geography and Geology of Lake Huron." This, one of the earliest descriptions of a geological section in that part of the country, recognizes (p. 196) the following formations: "Primitive rocks, Secondary, limestone with Orthoceratites on High Cliff Island, Red sandstone equivalent to the Old Red of Werner, underlying Lake George, and the Straits of St. Mary, and limestones at St. Joseph, and on Drummond Island, with Orthoceratites, Milliporæ, Madreporæ, Encrini, shells," etc. Some of the fossils are described and figured; they are all referred to the "Secondary." A Trilobite is also figured[1] and described by Charles Stokes.[2] This is plainly a Lower Silurian fossil, and its identification indicates the use of the term "Secondary" in 1824 as including part of what we now call Silurian rocks.

In 1825 Chester Dewey spoke of Eaton's survey of the Erie Canal[3] and recognized its value, but mildly protested against the "needless novelties in technical language."

In 1825 a letter[4] William Maclure urges "perhaps the most useful classification in the present state of the science would be to retain Werner's five classes as being well defined, that is, as well as the graded variety of nature will permit, and to make some subdivisions in each class without deranging the system already best known, or the ideas of those who follow it."

Thus it will be seen that, at this date, the ablest geologists of America adhered to the old Wernerian system of classification, and when we remember that this system was based upon a study of the primitive rocks, and that the classification which was applicable to them was applied to the whole series as well, we need not be surprised at the retarding influence exerted upon all true progress in geological science.

During the year 1826, and for several years after, frequent papers were published descriptive of coal mines, and dealing particularly with the properties of coal considered as a fuel and in its economical aspects. The regions discussed in these several papers were principally three,

[1] Am. Jour. Sci., vol. 8, p. 20.

[2] It is called by him *Asaphus platycephalus*, and figured on Plate 27, Figs. 1, a-b-c, and 2.

[3] *Am. Jour. Sci., vol. 9, p. 355.*

[4] *Ibid., p. 254, dated Paris, January 14, to the editor.*

those of Virginia, Pennsylvania, and Rhode Island, but in none of these papers was there expressed any very clear appreciation of the stratigraphic relations of the coal.

Two such papers were by James Pierce.[1]

In the first paper the author gave no opinion as to the geological age of the coal in Virginia, but in the second paper he referred the coal of Lehigh, Mauch Chunk, Easton, and Pottsville to the "Grauwacke formation," and regarded the Grauwacke as in the Transition group. This was a recognition of a lower horizon for the coal than had been accepted by the geologists in America. The coal heretofore discovered was regarded as belonging to the "Secondary formation" of the prevailing classification. The author also noticed that the coal in the eastern part of Pennsylvania is anthracite and the coal of the western deposits in Pennsylvania is bituminous.

Prof. Silliman, the editor of the American Journal of Science, also published several papers, about this time, on the coals of Rhode Island, Pennsylvania, and other regions.[2] But in his discussions on the coal, it is its properties and economical uses rather than its geological position which he considered.

In 1827, William Meade[3] considered the anthracite in the region from the Susquehanna to the Penobscot as decidedly belonging in the Transition. Reference was made by him to the coal lately discovered near the Tioga River, Pennsylvania.[4]

In 1828, Amos Eaton published in Albany a small treatise of some thirty-one pages, entitled "A Geological Nomenclature for North America."[5]

This publication is a revision of the "Nomenclature" published in the first part of the Erie Canal Survey of 1824, after suggestions received from Prof. Parker Cleaveland, Dr. Steele, and others. There are also some corrections based upon his own observations. Among the latter are to be noticed the statement that "there is no mica slate in Berkshire County on the western slope of the Green Mountain Range,"[6] and "no Primitive Argillite in our district;" "neither do I believe there is such a rock as Primitive Argillite on this globe," in which he follows Bakewell's opinion. Another modification is his statement that the "Old Red sandstone of Werner is not a general stratum," but is found in the third Graywacke, and also in the second Graywacke. In this view he follows Conybeare's opinion, as found in the Introduction of Phillips's and Conybeare's Geology.[7]

---

[1] The marl regions of Virginia and Maryland, and on the bituminous coal formation in Virginia; Am. Jour. Sci., vol. 11, 1826, pp 54–59. The mountain districts of Pennsylvania, and the mineral resources of that State, including its bituminous coal; ibid., vol. 12, 1827, pp. 54–74.

[2] Am. Jour. Sci., vol. 11, p. 78; ibid., 1830, vol. 18, p. 308; ibid., 1831, vol. 19, p. 1–21.

[3] Remarks on the Anthracites of Europe and America, Am. Jour. Sci., vol. 12, p. 76.

[4] Ibid., vol. 14, pp. 32–35.

[5] In the Am. Jour. Sci., vol. 13, pp. 145–159 and 359–368, is found substantially the same article under the title of Geological Nomenclature, Classes of Rocks, etc., by Prof. Amos Eaton.

[6] See op. cit. foot-note, p. 146.

[7] Ibid., pp. 147 and 155.

In the American Journal article, four pages, entitled "Geological Nomenclature Exhibited in a Synopsis of North American Rocks and Detritus," are inserted between the regular pp. 144 and 145, which appear to be a reprint of pages of the work as printed in Albany. This "Nomenclature" gives the following list of the classes of rocks:

CLASS 1. *Primitive rocks;* being those which contain no organic relics nor coal (including Granite, Mica slate, Hornblende rock, Talcose slate, Granular Quartz, Granular limerock).

CLASS 2. *Transition rocks;* being those which contain marine organic relics only, and in some localities Anthracite coal (including Argillite, First Graywacke, Sparry limerock, Calciferous sandrock, Metalliferous limerock, Second Graywacke).

CLASS 3. *Secondary rocks;* being those which contain, in some localities, dry-land or fresh-water organic relics, as well as marine, or bituminous coal (including Millstone grit, Saliferous rock, Ferriferous rock, Lias, Geodiferous limerock, Cornetiferous limerock, Third Graywacke).

CLASS 4. *Superincumbent rocks;* being those Hornblende rocks which overlay others without any regular order of superposition, and supposed to be of volcanic origin (including Basalt).

CLASSES OF DETRITUS.

CLASS 5. *Allurial detritus;* being those masses of detritus which have been washed into their present situation (including Anti-Diluvion, Diluvion, Ultimate Diluvion, Post-Diluvion).

CLASS 6. *Anallurial detritus;* being those masses of detritus which have not been washed from places, showing they were first formed by the disintegration of rocks (including Stratified Analluvion and superficial analluvion).

The localities are given for each of the above mentioned kinds of rocks, and we find them in Massachusetts, Connecticut, and New York, in the latter State mainly along the line of the Erie Canal.

A few of the names used in this "Nomenclature" are still retained, with no, or but slight, modification. "Calciferous sandrock," and under "Metalliferous limerock," "Birdseye marble" is mentioned as a variety of it; under the term "Third Graywacke," with the subdivision "Pyritiferous rock," is described what we now know as the Devonian rocks of the State of New York, including the Catskill, or what were known as the Old Red sandstone of Werner, but not including the Lower limestones. Eaton's "Cornetiferous limerock" appears to be a name covering both Lower Helderberg and Upper Helderberg rocks of our present classification, and his "Third Graywacke" rested upon the "Cornetiferous limerock." In this paper Eaton pointed out the distinction between "general strata," which he finds in America "can be traced for an extent of 100 or 300 miles," and "beds or varieties" of the former.[1]

According to this proposed nomenclature, "the Lias, Geodiferous limerock, Cornetiferous limerock, and the Third Graywacke occupied as uppermost rocks more than half of the great States of New York, Pennsylvania, Virginia, and nearly all the States of Ohio, Indiana, Illinois, Kentucky, Tennessee, and Michigan Territory," and he says

[1] Am. Jour. Sci., vol. 13, p. 361.

"If we adopt the European nomenclature, one must treat of this vast territory under the Oolitic Formation."[1]

Prof. Eaton regarded this synopsis as expressing accurately "the order of superposition," as well as the definition and geographical locating of the strata named.[2] In the same article he stated that "No one is qualified for examining geological facts, nor for reading essays or systematic treatises on geology, until he has fixed in his mind a systematic arrangement of general strata."[3] And he informed us that Van Rensselaer spent more than $18,000 on the investigations and researches which were carried on in connection with his survey of the Erie Canal rocks.[4]

In 1829 there appeared[5] an interesting article by J. E. Doornik on "Observations concerning fossil organic remains," communicated by the author in French, and translated by Charles U. Shepard. The author made some remarks upon M. Cuvier's method of explaining the importance of organic remains for geology. (Cuvier's "Ossemens fossiles" had been published in 1825.)

Doornik combats the proposition of Cuvier that "to fossil remains alone is due the origin of the theory of the earth, and that there had been in the formation of the globe successive epochs and a series of different operations," and while combating this proposition he defends Werner as having laid the foundation of geology.

This article is interesting particularly as showing the progress of science caused by the opposition of the conservatives. Fossils were rapidly taking the place of mineral characters in the correlation of stratified rocks, and the old school (such men as Doornik and Prof. Eaton) strenuously advocated the system of Werner. A quotation is found in this article from Brongniart, which shows how thoroughly he, as a student of fossil botany, appreciated the value of fossils. He wrote as follows:

> I consider, then, those characters relating to the epochs of formations which are taken from organic remains as of the first value in geology and as superior to all others, however valuable they may appear.

Lardner Vanuxem wrote a letter to Prof. Cleveland the same year.[6] Among other remarks the following are worthy of quotation: He said that the "Alluvial" of Maclure includes both Tertiary and Secondary, and the different deposits are characterized by their fossils, which are not confused or mixed, but are found at different levels, and this is noticeable in the Southern States particularly. He pointed out an error, which was a generally accepted one, and is traceable to the identifica-

[1] Am. Jour. Sci., vol. 13, p. 361.
[2] Ibid., p. 362.
[3] Ibid., p. 359.
[4] Ibid., note to p. 360.
[5] Am. Jour. Sci., vol. 25, p. 90, et seq.
[6] On the characters and classification of certain American rock formations. Am. Jour. Sci., vol. 16, 1829, p. 254.

tion of Amos Eaton, viz, the covering "of the western country and the back and upper parts of New York with Secondary rocks." Vanuxem found them, by their fossils, to belong to the Transition, and remarked: "The analogy or identity of rocks I determine by their fossils in the first instance and by their position and mineralogical characters in the second or last instance." He mentioned instances of such determinations in regard to certain rocks of Ohio, Kentucky, and Tennessee, which he identified with the "limestones of Trenton Falls by the genera of the fossils," and recognized that they are different from the rocks lying above the Coal Measures. This appears to be the first, or at least one of the very earliest, expressions in American literature of the principle underlying the new school of geologic correlation which soon after took the place of the Wernerian school.

To show how the errors of the system of Werner led to mistakes of identity, it may be noticed that Eaton's determination of the rocks of western New York, etc., as belonging to the "secondary rocks" of his classification, appears to be influenced by the term "floetz" of the Wernerian nomenclature, which applied to these rocks.

In 1830 James O. Morse published an article[1] in which is an illustration of the arguments used for defending the Wernerian system. The author referred to the doubt which had been expressed as to the identification of certain rocks with the Greywacke, and argued as follows:

> Prof. Jameson describes Greywacke as composed of sand connected together by a basis of clay slate, and minute inspection of the rock of these regions will convince any one that our Greywacke has these component parts.

Prof. Amos Eaton made some "Observations on the coal formations in the State of New York in connection with the great coal beds of Pennsylvania."[2] In this article he recognized four distinct coal formations in the United States: First, "the genuine Anthracite or Glance coal," in the Transition Argillite, Newport, Rhode Island, and Worcester, Massachusetts; second, "coal destitute of bituminous matter," not true anthracite, but what he calls "Anasphaltic coal," occurring in slate rock, lowest of the second series, which he identifies with the greatest Coal Measures of Europe, Pennsylvania, Carbondale, Lehigh, Lackawaxan, and Wilkes Barre; third, the "bituminous coal" proper, in slate rock of the lowest of the upper Secondary rocks, Tioga, Lycoming, etc., Pennsylvania; fourth, "Lignite coal," as seen at the south shore of the Bay of Amboy, in New Jersey. The first or "Anthracite coals" are represented by slates which he traced from Canada to Orange County, New York, but the coal never occurs in seams thicker than an inch. The third, "bituminous coal," Eaton traced from Pennsylvania to Seneca and Cayuga Lakes, and the coal seams, he said, were not over 2 inches in thickness. It is said to "rest on what the English call Carboniferous limestone." This "Carboniferous limestone" is plainly the Tully limestone, and the "Coal Measures" above are the Genesee shale.

[1] *Observations on the* Greywacke region of the State of New York; Albany Institute Trans., vol. 1, *pp. 84, 85.*

[2] *Trans. of the Albany Institute*, vol. 1., pp. 126-130.

Eaton identified the Onondaga Salt group and the Medina sandstone and shales, and Clinton rocks, probably, with the English "Saliferous" and underlying "Millstone grit," and in accordance with the English precedent coal was supposed to lie below these. He believed that boring at Gasport, 6 miles east of Lockport, which at the surface was 274 feet higher than the surface of Lake Ontario, would reveal the Coal Measures at 600 feet below the surface, and he was so confident that he even suggested that legislative aid be furnished for boring down to this coal. And again he says:[1] "And it may be stated that if coal is not found beneath the Saliferous rock, which is more than 200 miles in extent, it will be truly a geological curiosity which has no parallel on the Eastern continent; but we find many deviations in America from the geological maxims which seem to be established in Europe."

This mistake of the first of American teachers of geology of that time in supposing that coal would be found below the Middle Silurian rocks is the legitimate outgrowth of the imperfection of the Wernerian system. The supposition that Saliferous rocks occupy a particular place in a scale of strata was not Prof. Eaton's fault; he followed the English and they the German school in this, and it was not due to the ignorance of the uneducated that attempts were made to find coal in New York State for years after this, but it was due to the ignorance of the best geologists of the time as to the right means of correlating rock equivalents across the Atlantic.

In 1830 Amos Eaton wrote a short article[2] entitled "Geological Prodromus." He announced that he intended to demonstrate that "all geological strata are arranged in five analagous series, and that each series consists of three formations, viz: the Carboniferous, Quartzose, and Calcareous." He referred to Bakewell's classification, and this idea is evidently a modification of the notion that strata were arranged in recurring suites of formations, a notion which was brought out in the later development of geology, in the theory of "circles of sedimentation," of which Dr. J. S. Newberry is the most conspicuous exponent.

Eaton particularizes in the article referred to, saying that he intends to show that "the Lehigh or Lackawannock coal * * * is embraced in the Second Grauwacke, Secondary, and that the Tioga coal is embraced in the Third Grauwacke or Upper Secondary of Bakewell and others"; and in this latter position, the Third Grauwacke, he mentions as belonging to the "thin layers of coal at Ithaca, on Seneca Lake, and Lake Erie shores."[3]

This error of Eaton's in identifying the rocks of Ithaca, Cayuga Lake, and westward to Lake Erie with the "Third Grauwacke," placing them above the Blossburg coal of Pennsylvania, was not corrected until several years later, when the study of fossils clearly revealed the fact that the rocks belonged below the Carboniferous.

[1] Am. Jour. Sci., p. 130. [2] Ibid., vol. 17, p. 63, dated Troy, July 28, 1829. [3] Ibid., p. 28.

The classification of De la Bêche is reported in the Journal,[1] a few points of which may be worth recording in order to show how opinion stood in England at this time. The rocks from the top down to what is called "the lowest fossiliferous" are divided into nine groups, and together are called "the superior stratified or fossiliferous rocks." These divisions are as follows:

1. Alluvial Group.
2. Diluvial Group.
3. Lowest Great Mammiferous.
4. Cretaceous.
5. Oolitic.
6. Red Sandstone.
7. Carboniferous.
8. Grauwacke.
9. Lowest Fossiliferous.

In this classification is seen also a separation of the Old Red sandstone from the Carboniferous, placing the Old Red in the eighth division, the Grauwacke.

Eaton identified the second coal with the formations below the "Saliferous," and the third coal, he stated, is the same with the outcrops in Ithaca and on Cayuga Lake.[2]

This opinion was controverted by David Thomas, who dates his article, Greatfield, Cayuga County, New York, 1830.[3] He pointed out the fact that the rocks on Cayuga Lake dip slightly to the south, which would bring them below the Tioga coal, and he modestly differed from the distinguished geologist, Prof. Eaton, and suggested that these rocks on Cayuga Lake must belong to different strata, below the coal deposits of Tioga, Pennsylvania.

In 1831 Silliman compared conglomerates associated with the anthracite coal in Pennsylvania with the Millstone grit of the English Coal Measures;[4] in 1832[5] Eaton supposed that he had established identity for the rocks in New York with European strata by their contained fossils, for "(1) Granular limerock with no organic remains; (2) the Metalliferous, mountain, or Carboniferous limerock," which he recognized by fossils in the rocks from Glens and Trenton Falls, Bethlehem, Catskill, Esopus Strand, and Rondout. "(3) The Oolitic series of calcareous rocks, the 'coral rag,'" recognized on the south shore of Lake Erie, and 23 miles southwest of Albany. "(4) Tertiary marls," recognized in New Jersey as "London clay," and "shell marl" in the bank of the Erie Canal, 10 miles west of the Onondaga Salt Works.

This article is dated October 2, 1831; the identifications, as it will be seen, are mainly utterly wrong, although the attempt shows how the principle of correlation by means of fossils was being forced into notice and adopted by even the extreme disciples of Werner.

In the same year and volume[6] Eaton published another article, enti-

[1] De la Bêche, Henry. Sketch of a classification of the European rocks. Am. Jour. Sci., vol. 18, 1830, pp. 26–39.

[2] Albany Institute, Transactions, vol. 1; also Am. Jour. Sci., vol. 19, pp. 21–26.

[3] Am. Jour. Sci., vol. 19, p. 326.

[4] Ibid., pp. 21–26.

[5] "On the four cardinal points in Stratigraphic Geology, established by organic remains." Am. Jour. Sci., vol. 21, pp. 199–200.

[6] Ibid., pp. 132–138.

titled "Geological Equivalents," in which is given a list of "names of strata which are known to geologists of both continents, with some of their organic associations in North America." In the list eighty species are named. The names were taken, of Mollusca, chiefly, from Sowerby, of Radiata, from Goldfuss, of Crustacea, from Brongniart. It is an attempt to recognize the European strata in America, adopting the Bakewellian adaptation of Werner's system, and there are necessarily many gross errors.

In an article in the American Journal of Science, Prof. Silliman, the editor, reviewed "Phillips's Geology of Yorkshire," which had been published in 1829. In the course of his remarks we find the following statement: "Werner and Smith are, therefore, the leaders of the modern school of geology," and "Smith has the great merit of establishing the facts that different strata contain different fossils, but that the same stratum over a very large extent of country contains generally the same fossils, hence he deduces the important conclusion that strata may be discriminated and indentified by their organic contents."[1]

Edward Hitchcock reported[2] on the "Geology of Massachusetts," which he had examined under the direction of the government of that State, during the years 1830–'31. Part first, or economical geology, was published in the Journal, and in a foot-note the editor said that "this is the first example in this country of the geological survey of an entire State." In this report the Connecticut River sandstone is called the "New Red sandstone," the opinion formerly expressed in regard to coal occurring in Connecticut and Massachusetts is reconsidered, and in the present article the coal formation of this region is regarded as belonging to the New Red sandstone or its equivalent.[3] The Worcester anthracite is regarded as in older rocks than that of Rhode Island, and the Pennsylvania anthracite is reported as occurring in the higher beds of the Grauwacke, and as belonging to a newer horizon than that of the Rhode Island coal.

Geo. W. Featherstonhaugh[4] did little more in the way of classification than theoretically to adapt the system of Conybeare to America. The table of formations is as follows: (details only of the parts pertaining to the present discussion are here given):

			Feet.
Secondary..	Supermedial order..	17. Lyas.....	
		16. Variegated or red marl	500
		15. Muschelkalk	300
		14. New Red sandstone	300
		13. Zechstein	500
		12. Exeter red conglomerate.....	500
	Medial order	11. Coal beds	1,000
		10. Millstone grit and shales.....	800
		9. Carboniferous limestone	850
		8. Old Red sandstone	1,500

[1] Am. Jour. Sci., vol. 22, pp. 4, 11–12.

[2] Ibid., pp. 1–70

[3] Ibid. p. 43.

[4] Featherstonhaugh, G. W. : On the order of succession of the rocks composing the crust of the earth. Monthly Am. Jour. Geol. and Nat. Sci., vol. 1, 1832, pp. 337–347.

Transition....Submedial order.... { 7. Greywacke.....
6. Transition sandstone .....

In 1833 Eaton gave reasons for referring the Pennsylvania coal beds to the Secondary Coal Measures of Europe.[1] In this article reference is made to coal plants collected by Mr. James Hall, then adjunct professor in Rensselaer Institute. Eaton defended his reference of the coal beds of Pennsylvania to the "Secondary," and mentioned his identification of twenty-three species of the specimens of ferns collected by Hall with species described by Brongniart from the great Secondary coal formation.

J. B. Gibson, in 1833, recognized in Pennsylvania, New York, Upper Canada, Ohio, and Michigan, two superior formations: the *New Red sandstone*, associated with which he reports Magnesian limestone, gypsum, and rocksalt; resting on this is a *calcareous formation*, forming the cataracts of Niagara, Onondaga, and Genesee.[2] Of the limestone along the Niagara River he said:

> It corresponds in all material respects to the Lias of the English geologists and corroborates the German doctrine of universal formations.[3]

And more of the same kind.

Bituminous coal in Alabama was reported by Alexander Jones in 1834, and a section was run across the country from Baltimore to the Ohio River by William E. A. Aiken.[4]

In 1834–'35 the Transactions of the Geological Society of Pennsylvania, vols. 1, 2, were published.

Richard C. Taylor had several papers in these transactions in regard to the geological position of the coal deposits of Pennsylvania and Richmond, Virginia.[5] He recognized in the plants from Lewistown, Mifflin County, Pennsylvania, "marine plants of the family Fucoids, from the Grauwacke group, and the Old Red sandstone."[6] In one article Taylor shows that coal is not to be expected to the northward, as the dip of the rocks is southward. In Pl. 8, Fig. 5, the true relation of the beds from Blossburg northward to the Chemung River is given, and from observations made upon the dip of the rocks, decreasing northward, he estimated that the rocks at the Chemung River, "Chimney Narrows," would be 6,275 feet below the summit of the hills of the Tioga Basin. These beds below the Blossburg coal basin are called "Old Red sandstone," and he regarded them as 6,000 or 7,000 feet thick.[7]

---

[1] The coal beds of Pennsylvania equivalent to the great Secondary Coal Measures of Europe; Am. Jour. Sci., vol. 23, p. 309.

[2] This is the Niagara limestone.

[3] Am. Jour. Sci., vol. 23, p. 203.

[4] Aiken, Dr. William E. A.: "Some notices of the geology of the country between Baltimore and the Ohio River, with a section illustrating the superposition of the rocks." Am. Jour. Sci., 1st ser., vol. 26, 1834, pp. 219–232.

[5] Vol. 1, pp. 5–15.

[6] Pp. 204–223: "On the mineral basin of the coal field of Blossburg, on the Tioga River, Tioga County, Pennsylvania."

[7] *P. 208.*

Of fossils he named the following as occurring in these beds: "*Producta* and *Crinoidal* remains, and occasionally *Fucoides*, *Carophyllea*, *Pectens*, and *Spirifer* are interspersed." This is, apparently, the first identification of the Chemung group, as it is now called, of the Upper Devonian.

He discussed[1] "a section passing through the bituminous coal field near Richmond, Virginia," and gave a full account of "these interesting beds of coal," which he regarded as "probably of Transition age" rather than Secondary, to which position Mr. Maclure referred them.

At that time, apparently, the fossils had not been studied, ignorance in regard to which left the geologists in the dark as to the true position of these Mesozoic deposits.

An account is given[2] of studies of sections for 250 miles across Virginia and Maryland. In the discussion the Primitive, Transition, Old Red, and Secondary rocks are recognized, and the Fredericksburg plant beds were referred[3] to the "Oolitic" of Europe.

In another paper the coal beds of the Alleghany Mountains are called "Secondary, with Old Red Sandstone lying under them," and on the other side of the anticline were seen other coal beds, which Mr. Taylor called "Transition." A cut is given[4] presenting the true relations of the Chemung and Blossburg deposits, but the Blossburg coal is regarded as Secondary.

In the same Transactions,[5] Edward Miller described a portion of the Alleghany Mountains, in which he recognized the coal formations as belonging to the "Coal Measures."

Gerard Troost,[6] in a paper on certain Pentremites found in Tennessee, Alabama, and Kentucky, identified the rocks of Perry County, Tennessee, as "a stratum below the Coal Measures," regarded by him as "in the Upper Transition." In the same rocks with the *Pentremites* were found *Trilobites*, *Calceola sandalina*, *Calamopora*, *Terebratula*, *Spirifera*, *Producta*, etc.

In some cases the limestone had an oolitic structure. The limestone near Nashville, Tennessee, was referred to the "Mountain limestone of the English." The conclusion is that the beds containing the Pentremites of these Southern States characterize "the Upper Transition limestone" of the interior of America.

The same author[7] wrote "On the organic remains which characterize the Transition series of the Valley of the Mississippi." In this article he included "Mountain limestone" in the "Transition strata," be-

[1] On pp. 276-294.

[2] On p. 314.

[3] Vol. 2, pp. 177-193: "On the relative position of the Transition and Secondary coal formations in Pennsylvania, and description of some Transition coal, or bituminous, anthracite, and iron-ore beds near Broad Top Mountain, in Bedford County, and of a coal vein in Perry County, Pennsylvania, with sections."

[4] P. 194.

[5] Vol. 1, p. 251.

[6] Ibid, pp. 224-231.

[7] Ibid., 248.

cause, as he says, "the fossils of the Carboniferous limestone are those found in the Grauwacke of Europe, while his Grauwacke is without fossils except in the upper strata." The "Carboniferous limestone" he considered distinct from the "Coal Measures."

In 1836 S. P. Hildreth recognized in the State of Ohio, using the nomenclature of De la Bêche, the "Tertiary, Super-Cretaceous, New Red sandstone, Red marl, White Lias limestone, Millstone grit or Breccia, Bituminous coal, Old Red sandstone." The "Pittsburg coal strata" and the "Carboniferous limestone" are described. An "extensive spring of petroleum" is mentioned. A large number of fossils are figured, thirty plates of which are published with names and short descriptions.[1]

In 1836 Featherstonhaugh [2] compared the deposits of anthracite coal and bituminous coal, and stated that the former belongs to an entirely distinct geological position from that of the latter. The "anthracite," with the exception of Broad Top in Bedford County, Pennsylvania, is "without exception deposited low down among what have been called the Grauwacke rocks." And he thinks they will prove "the equivalent of Mr. Murchison's Silurian rocks."[3]

In 1837, George E. Hayes [4] gave his reasons for differing from those who considered the rocks of western New York as of Secondary age. He regarded them as "older than the Carboniferous" and of Transition age."

In 1838 Charles T. Jackson, speaking of the Coal Measures of Mansfield, Massachusetts, refers them to the "Conglomerate or Grauwacke."[5]

This brings us up to the time of the Geological Survey in New York, and the work of the Rogers in the Pennsylvania and Virginia rocks, and the clearing up of the classifications, due in great measure, for the lower rocks, to the publications of Murchison and Sedgwick in England, which had then reached America. It is interesting to notice that so long as the Transition and Grauwacke rocks were classified in accordance with the Wernerian system, nothing satisfactory was reached. The Coal Measures, the Saliferous rocks, the Grauwacke, the Old Red sandstone, and the Carboniferous limestones, when attempts were made to identify them in this country, were placed in the positions to which they were assigned by the Wernerian school; position being determined not by study of their stratigraphy alone, but by the primary identification of the rock from its mineralogical characteristics, which were supposed to be recognized, and then by an arbitrary reference of it to a position in the system corresponding to that found in the European series.

---

[1] Observations on the bituminous coal deposits of the valley of the Ohio, and the accompanying rock strata, with notices of the fossil organic remains and the relics of vegetable and animal beds. Am. Jour. Sci., vol. 29, pp. 1–154.

[2] Report of a geological reconnoissance made in 1835, from the seat of Government by the way of Green Bay and the Wisconsin Territory to the Coteau de Prairie.

[3] Op. cit., p. 113.

[4] *Am. Jour. Sci.*, vol. 31, pp. 241–247.

[5] *Ibid., vol. 34, p. 395.*

The new school of geologists, when they began work in New York State, made careful stratigraphic observations. Following the methods begun by Murchison and Sedgwick, although taking the data from the facts as they found them, they arrived at a correct interpretation of the strata of New York, which are peculiarly simple in their stratigraphic relations. And ultimately the "New York system," as it was afterward called (the name was proposed as a temporary name for convenience), became the standard section for American Paleozoic rocks. This New York system of rocks is for the Paleozoic one of the most perfect and satisfactory geologic sections found anywhere in the world, and may well stand as a classic section for the interpretation of the rocks which had been called Transition in the older nomenclature.

In 1837, the first annual report of the Geological Survey of New York was published. In this report, T. A. Conrad, who had previously studied the paleontology of Tertiary deposits along the coast, and was recognized as a paleontologist of ability, reported for the third district of New York. In classification, the nomenclature of Eaton mainly was used. We notice[1] that in the main the strata he studied were recognized as belonging to "the Silurian or Lower Transition rocks. Thus it will be seen that the Murchisonian classification had already reached America.

In this first report special attention is called to the importance of having the fossils carefully studied by a man specially appointed for that purpose, as State paleontologist. The next year Conrad was appointed paleontologist.

In the second report, 1838, Conrad, as paleontologist, reported the following points, which will show the progress that had been made during the year. He concluded that with the exception of the upper part of the Catskill Mountains, the rocks of the State terminate with the "Upper Ludlow rocks" of Murchison; and he noted that the fossils in the strata below the coal in Tioga County are the same as those in the Coldbrook Dale coal, and also that the same fossils are recognized in Ohio.[2]

Among the fossils discovered in the various strata he found what he regarded as equivalents of those reported from foreign rocks in the following places:

(1) Below the Catskill strata fossils equivalent to those of the Ludlow.[3]

(2) A limestone and two strata of sandstone with fossils equivalent to those of the Dudley.[4]

(3) The "Calciferous slate" of Eaton, containing the gypsum, was correlated with the "dye earth" of Shropshire.[5]

(4) The "Saliferous sand rock" of Eaton, was the Red sandstone at Niagara and Genesee Rivers (now the Medina sandstone.[6])

[1] Op. cit., p. 184.
[2] Op. cit., pp. 109, 110.
[3] *Ibid., p. 110.*
[4] Ibid., p. 111.
[5] Ibid., p. 112.
[6] Ibid., p. 113.

(5) Olive sandstone and slate of Salmon River, Oswego County (these two, 4 and 5 were recognized as equivalents of "the fourth group in the slate system of Wales," as defined in Phillip's Encyclopædia Metropolitana, article Geology, p. 568.)

(6) The black limestone and shale of Trenton, the "Birdseye limestone," and "calciferous sand rock" of Eaton, and the grauwacke and slate of Hudson River, he recognized as equivalent to the "Llandeilo flags" of Murchison.[1]

In this report, also, thirteen species of fossils are described from the first group above, which he regarded as equivalent to the Ludlow.[2]

The localities given are Norwich, Cazenovia, Madison, and Sherburne. Since all these localities are Devonian localities, and the fossils are Devonian fossils, it is evident that in 1838, the paleontologist Conrad regarded these Devonian rocks as equivalent to the Ludlow group of the Upper Silurian of Murchison.

Lardner Vanuxem reported for the third district[3] and appears to follow Eaton's nomenclature, except in a few new names, like "Trenton limestone," which had already been published. Fossils are given for "Trenton limestone, black shale," "green shale and sandstone," "upper limestone," "white sandstone" (which can be recognized as the Oriskany). The species in this report were evidently determined by Conrad.

James Hall reported for the fourth district. This, it will be remembered, includes the rocks of the State from Cayuga Lake westward. These rocks were regarded as equivalents of the Old Red sandstone and Carboniferous groups, and stratigraphically above the Silurian system of Murchison.[4] Some erroneous identifications, however, are evident; what is now the Medina sandstone was called in this report "Old Red sandstone," and the Corniferous limestone was identified as "Carboniferous or Mountain limestone."[5]

W. W. Mather, in 1838, published the first annual report of the Geological Survey of the State of Ohio. In his identifications he mentioned first the great limestone deposit, which he correlated with the "Mountain or Carboniferous limestone" of Europe. He defined this as covering the western border of the State. He named a number of fossils from this limestone, which are evidently erroneously identified, as the formation is Silurian, and not Carboniferous, as he supposed. His third formation he called "Waverly sandstone series." Other points of the correlation were made, as "conglomerates," and also an "upper coal series," but it is particularly important to notice that originally the formations called "Carboniferous limestone" in America were not correctly identified.

The second annual report of the Geological Survey of Ohio was

[1] N. Y. Geol. Surv., 2d Rep., p. 114.
[2] Ibid., p. 116.
[3] Ibid., pp. 253–286.
[4] *Ibid., p. 291.*
[5] *See "map along the Genessee River from Rochester southward."*

hed in 1838. The director of the work, and editor-in-chief, was . Mather. The volume contains reports by Mather,[1] C. Whit-,[2] J. W. Foster,[3] C. Briggs, jr.,[4] and J. Locke.[5]

he geological parts of this report we have general descriptions regions surveyed and some location of the order of the strata, n particularly in a "table representing the geological structure io,"[6] prepared by C. Briggs, jr., which is as follows:

rocks of the State are divided into six formations, which, from downward, are in the following order: "(1) Alluvium, (2) Ter- (3) Coal Measures, (4) Fine-grained sandstone, (5) Shales, and ountain limestone."

"Mountain limestone (6)," which is said to be about a thousand thickness, and is defined as "beds of limestone intermixed with judging from the localities in which it is identified, is probably rniferous limestone. The "Fine-grained sandstone (4)," underly- e Coal Measures, is apparently the "Waverly sandstone series" first report.

John Locke's report[7] a generalized section of the southwestern f Ohio is given. In this section the following deposits are recog- beginning at the bottom with "(1) Blue limestone," [the Cincin- imestone], "(2) Marle, (3) Flinty limestone, (4) Marle, (5) Cliff one, including basins of iron ore, (6) Bituminous slate, and (7) grained sandstone."

ill be seen from this report that nothing had been done to cor- accurately the deposits with any of the systems then in use. r was one of the corps of geologists engaged in the State survey v York, and it was not until later than 1838 that the New York gists had adopted any systematic classification of rocks.

Houghton's report of the survey of Michigan, the coal formation ecognized, but the classification was not correlated with the can system, and merely the nature of the rocks and their order lefined.

Indiana identifications had been made of the "coal formation" 'Subcarboniferous rocks," including the "Oolitic limestone, ulic limestone, etc.," which were rightly identified in their strati- ic relations to the Carboniferous. They were regarded by D. D. as similar to the Mountain limestone of the Europeans.[8]

Tennessee (fourth report, by G. Troost), the "Primordial," the wacke," the "Mountain limestone," and the "Coal Measures" listinguished, and an immense deposit of sandstone was recog- between the Grauwacke and the Mountain limestone which was led as equivalent to the Old Red sandstone of the European geol-

[9]

[1] Pp. 1-40.
[2] Pp. 41-72.
[3] Pp. 73-107.
[4] Pp. 109-154.
[5] Pp. 203-286.
[6] Loc. cit., p. 108.
[7] See p. 205.
[8] See Am. Jour. Sci., vol. 34, p. 193.
[9] Ibid., p. 187.

Pennsylvania: H. D. Rogers had been studying the rocks of Pennsylvania, and there was published in this year a generalized section of the Appalachian region of Pennsylvania.[1] The formations recognized by Rogers were as follows:

1. Sandstone of South Mountain.
2. Limestone of Kittatiny Valley.
3. Slate of Kittatiny Valley.
4. Sandstone and conglomerate of Kittatiny Valley and Blue Mountain.
5. Red and variegated sandstone and shale of the valley northwest of Kittatiny.
6. Blue limestone along the north base of Kittatiny and both sides of Montour's Ridge.
7. Sandstone of the first ridge north of Kittatiny.
8. Olive-colored slate of the valley between Kittatiny and second mountain.
9. Red sandstone and shale of southeast slope and base of Alleghany Mountains.
10. Sandstone and conglomerates of second mountain, and of southeast summit of Alleghany.
11. Red shale of anthracite coal regions.
12. Conglomerates and sandstones immediately below the Coal Measures (Broad Top and Alleghany coal region)
13. Anthracite Coal Measures.

It is interesting to note that this system of numbers for the various formations was made out about the same time that the system of nomenclature adopted by the New York Survey was being formed. Both systems have struggled for existence in some parts of the country. The system of Rogers was one based strictly upon the nature of the rocks and their stratigraphic sequence, and in so far is satisfactory for that particular region; but the New York system was defined in addition by the fossil contents of the various formations, and an attempt was made at the very start to correlate them with the several formations defined by the European geologists.

Whether we adopt local geographical names or not, it is doubtful if simple numbers, as proposed in the Pennsylvania system of Rogers, will ever be satisfactory except for a limited region.

In this same year, 1838, we have a report upon the Upper Illinois, by C. U. Shepard.[2] The name "Magnesian limestone" is applied to the "great limestone rock formation extending from near Chicago to the Kankakee River," and in various places the coal formation was recognized. Several sections of the coal formations and descriptions and figures of some plants and fossil shells are given.

Prof. Dewey, of Rochester, gave an account[3] of some observations on the rocks in western New York. The rocks south of Rochester were misunderstood by him on account of the misinterpretation of the fossils; for instance, the "limestones" were regarded as the same as those of Trenton Falls, and as belonging to the Transition, and were

[1] See Am. Jour. Sci., vol. 34, pp. 189, 190.
[2] Ibid., pp. 134-161.
[3] Ibid., vol. 33, pp. 121-123.

ught to "rank with the Mountain limestone of Europe, and rest on Old Red sandstone."[1] By the latter term he evidently meant the dina sandstone.

In 1839, T. A. Conrad published "Notes on American Geology."[2] used the term "Trilobite rocks" for what had previously been led the Transition or the Silurian system. In this paper he stated at "Strophomena is the most characteristic of the Trilobite system;" at "Producta has as yet been found only in the upper term," or Pyritiferous rock" of Eaton, and that the "Producta is abundant in Mountain limestone where Strophomena is rare," and that this nus is "eminently characteristic of the Carboniferous system." This licates a careful observation of fossils, although the identifications broader than customary at the present time.

In 1839, Whittlesey, Ch., recognized the following classification of rocks of Ohio:

1. Coal Measures.
2. Conglomerate.
3. Waverly series.
4. (Black shale, Hamilton and Marcellus).
5. Cliff limestone (including Corniferous and Onondaga).

The "Hamilton and Marcellus shales" extended from the lake to the se of the Newburg section. "Chemung and Portage" included the ks of Newburg and Bedford and above to about half way to Hudson.

Murchison, in his "Silurian System,"[3] London, 1839, proposed the lowing names.

Oolitic system.[4]	Silurian system.[8]
New Red system.[5]	Upper Silurian rocks.[9]
Carboniferous system.[6]	Lower Silurian rocks.[9]
Old Red system.[7]	

d quotes the term "Cambrian System,"[7] from Prof. Sedgwick. The rds, "Oolitic," "New Red," "Carboniferous," "Old Red," were names ed before and applied to certain rocks, but their use in connection h the word, "system," is apparently introduced for the first time by rchison.

The following is the classification proposed by Murchison as it apars upon his map:

Inferior oolite	Oolitic system.
Upper lias and marlstone	
Lower lias	
Upper red marl	New Red system.
Keuper sandstone	
Lower Red marl	
New Red sandstone	
Calcareous Conglomerate (Magnesian limestone)	
Lower New Red sandstone	

[1] Am. Jour. Sci., vol. 33, page 123.

[2] Ibid, vol. 35, pp. 237-251.

[3] The Silurian System, founded on Geological Researches in the counties of Salop, Hereford, Radnor, ntgomery, Caermarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester, and Stafford, with criptions of the coal fields and overlying formations. By Roderick Impey Murchison, F.R.S., etc. wo parts. London, 1839. Quarto, 768 pp., 37 plates, and large folding map.

[4] P. 13. [5] P. 27. [6] P. 79. [7] P. 169. [8] P. 195. [9] P. 265.

g. Upper Coal and Fresh-water lime			Carboniferous system.
g. Lower Coal Measures			
h. Millstone grit			
i. Carboniferous limestone			
k. Old Red Conglomerate			Old Red system.
l. Cornstone and marls of Old Red			
m. Tilestone of Old Red			
n. Upper Ludlow rock	Ludlow	Upper Silurian rocks.	Silurian system.
n. Aymestry and Ludlow limestone			
n. Lower Ludlow rock			
o. Wenlock limestone	Wenlock		
o. Wenlock shale			
p. Upper Caradoc (with limestone)	Caradoc	Lower Silurian rocks.	
p. Caradoc sandstone			
q. Llandeilo flags (and limestone)	Llandeilo		
r. Upper Cambrian (beds of passage)			Cambrian system (part of).
s. Slaty Cambrian rocks			

M. de Verneuil[1] gave the following classification:

Carboniferous System	1. Coal Measures and Millstone grit. 2. Mountain limestone. 3. Lower Carboniferous shales.
Silurian System	1. Upper Silurian (including Old Red sandstone and Devonshire strata). 2. Middle Silurian. 3. Lower Silurian.

Thus evidently following Murchison, and he pointed out the error of Foster of Ohio and other American geologists in identifying limestones containing Silurian fossils as "Mountain limestone."

In the same journal, in the following year (1841), J. W. Foster explains that the Silurian fossils came from a formation wrongly called by him "Mountain limestone."

In a review of the report of the geological and agricultural survey of the State of Rhode Island, by Charles T. Jackson,[2] the reviewer gave the following opinion: "In determining the geological age of rocks Dr. Jackson gives a preference to superposition of strata and the mineralogical composition over zoological and botanical characteristics, which, however, he allows to be of great value. He prefers also the Wernerian division of Transition rocks to the names Cambrian and Silurian proposed for certain groups in England, which he thinks will never be regarded in this country as appropriate terms for our rocks."

This is an indication of the prejudice which is not confined to the old geologists or to the early stages of geological science, but which troubles us at the present time. The names "Cambrian" and "Silurian," within 10 years of the time when Jackson wrote this, were almost universally adopted by Americans whenever the formations included under these names were under consideration, and the Wernerian system, for which Jackson and many of his associates at that

[1] Verneuil, Ed. de: Sur l'importance de la limite qui sépare le calcaire montagne des formations qui lui sont inférieures. Soc. géol. France, Bull., 1840, vol. 2, pp. 166–179.

[2] *Am. Jour. Sci., vol. 40, 1840, pp. 182, 183.*

time strenuously fought, has been entirely superseded. Attempts to fetter the progress of science by holding on to established systems are always to be avoided, and those who have the interests of true science at heart should jealously watch against the prejudices which tempt them to cling to those things which have been, merely because they have been.

In 1840 Conrad published a paper "On the Silurian system, with a table of strata and characteristic fossils."[1] This paper appears to be in its essential features the same as the table published in the fifth annual report of the State of New York in the following year. He had studied the Silurian system of Murchison and found spread over the greater part of New York, Ohio, Indiana, Kentucky, and Tennessee, and terminating on the south in the mountains or hill regions of north Alabama, rocks which represented the Silurian system. He reported in the vicinity of Florence and Tuscumbia, Alabama, the "Oriskany sandstone." At Blossburg, Pennsylvania, the "Old Red sandstone" was recognized by the presence of *Holoptychius*. On the western slopes of the Appalachian he found the Carboniferous system well developed, with the Mountain limestone rare and generally in thin deposits. The "New Red sandstone" was recognized in very limited areas. No traces of the "Oolitic," the "Lias," or "Wealden" were recognized. The "Cretaceous" was widely distributed and the "Tertiary formation" was reported as occurring on the sea border.

In New York State the "Llandeilo flags" were recognized and the "Caradoc sandstone" was regarded as the equivalent of the "Trenton limestone." The "Wenlock shale" was recognized in the "Rochester shale" and the "Calciferous slate" of Eaton. The "Wenlock limestone" was identified in the "Helderberg limestones," six of them. The "Ludlow rocks" were not defined in this paper. A table is given[2] showing the characteristic fossils of each of the formations and their English equivalents as represented in Murchison's Silurian system. This paper is particularly interesting as the first exhaustive attempt to correlate the formations of America with those of Murchison's Silurian system by means of their fossils alone. Previous attempts had been made by him to correlate the New York rocks with the English rocks in general.[3]

In a notice, by O. P. Hubbard, of the third annual report on the Geological Survey of New York,[4] a few remarks are made which show the confusion which existed at this time regarding the classification of the New York rocks. He shows that there was considerable difference of opinion as to the position of the rocks in central and western New York. "They have been alternately described as Transition and Secondary." "The Saliferous group" is counted as above the coal series,

[1] Am. Jour. Sci., vol. 38, pp. 86–93.
[2] Ibid., pp. 89, 90.
[3] See New York annual reports.
[4] Am. Jour. Sci., vol. 39, pp 95–108.

and this with the "sandstone of Rochester" is regarded as New Red sandstone. The rocks of the fourth district are considered as belonging to the "Old Red sandstone and the Carboniferous group," and to lie "above the Silurian system of Mr. Murchison," a conclusion based in part upon the organic remains.

This confusion was doubtless due to the fact that the Wernerian method, which, somewhat modified, was seen in the earlier works of Eaton, was inconsistent with the new method which was being elaborated by the New York State geologists. Those who thought in terms of the first considered the new method revolutionary.

Prof. Eaton's systematic work heretofore followed the English treatise on geology by Bakewell. In an article which appeared in 1840[1] he quotes an outline of the system of Brongniart, proposed in 1829, which he states the author still maintained in 1840. As Eaton used this system and attempted to defend its application to American rocks, it may be worth while to record Brongniart's system of classification:

1. Primitive class (Agalysient, overthrowing or breaking up by internal forces).
2. Transition class (Hemilysient, half breaking up by internal forces).
3. Lower Secondary class (Abyssient, deepest abyss of the ocean).
4. Upper Secondary class (Pelagient, the ocean).
5. Tertiary class (Thalassient, the sea).
6. Diluvial class (Clysmient, the deluge).
7. Alluvial class (washed).

It will be seen from the terms used that Brongniart considered the rocks to be formed in the Primitive class by the overthrowing or breaking up processes due to internal forces; the Transition class, half to this operation; the Lower Secondary class, to the sedimentation of the deep abyss of the ocean; the Upper Secondary, to the ordinary deposition of the ocean; the Tertiary, to the shallow seas or modern seas; the Diluvial, to floods or deluges on the land; and the seventh, Alluvial, to the washing of rivers and streams.

The general theory of this interpretation of the strata was proposed earlier by Lehmann, and is associated with the general notion that the earth was formed from water solution—first, by a chemical crystallization and deposition, and later by sedimentation from the ocean, at first higher up in the hills, and, as the water evaporated, lower down in the valleys. This general theory pervades various systems of the early part of the century, and may be regarded as the fundamental theory of Werner, determining his method of classification and of correlation.

In the present article, Eaton attempted to point out the limits between the various divisions of Brongniart in our own strata. He recognized the well known Stockbridge marble of Massachusetts as the upper stratum of the Primitive class. Second, he regarded the "Cor-

[1] Amos Eaton: References to North American localities to be applied in illustration of the equivalency of geological deposits on the eastern and western sides of the Atlantic. Am. Jour. Sci., vol. 39, p. 149.

niferous limerock" as the uppermost Transition rock. This he identified further as equivalent to "some part or most of the Grauwacke group of De la Bêche, the Grauwacke limestones of some English writers, the Grauwacke slate of Bakewell, and perhaps the Carboniferous rock of Conybeare, and, surely, the Upper Transition (one of the Psammite) rocks of Brongniart."[1]

The limit between the Secondary and Tertiary, Eaton recognized along the south shore of Raritan Bay, in New Jersey. He says. "Uppermost of the Secondary deposits is the Cretaceous formation most perfectly characterized, but it contains no white chalk; the last of the Tertiary is the plastic clay.[2]

There is nothing particular valuable in this article, or new, even at that time, but the particular importance of quoting it is to show how the Wernerians were beginning to recognize the absolute importance of fossils in determining the relations of deposits.

In 1841 A. Clapp[3] correlated the "limestone of the Falls of the Ohio" with the Wenlock of Murchison; it is the "Cliff limestone" of Locke. The "limestone and marls of Madison and Hanover, Indiana" are correlated with the Wenlock; the "Middle and Lower Blue limestone and marls" of Cincinnati are correlated with the Caradoc; the "black bituminous shale" at the foot of the Falls is considered as equivalent to the Marcellus shale of New York; the "Oolitic" and the "Pentremite limestone" of Troost and Owen, of Kentucky, Indiana, and Illinois are identified as Carboniferous limestone. The author considered the "limestone of the Falls of the Ohio" in its upper portion to be identical with the Ludlow and Wenlock, the lower and middle portion as equivalent to the Niagara limestone and Gypseous shales of New York, and he further correlated the "Cliff limestone" of Locke with the whole of the rocks represented in New York by Niagara limestone, Gypseous shale, Water-lime, and Onondaga limestones. This constitutes the total rock deposit between the "Blue limestone and marls of Cincinnati" and the "Black shale" (Marcellus), and is the western continuation, as he says, of the Middle Silurian of Conrad. The 8 feet of fetid subcrystalline limestone immediately underlying the Black shale the author identified with the New York Water lime, and the "Black shale" above it he regards as not equivalent to the Ludlowville shale, as was asserted by Prof. Hall, but as lower and the true equivalent of the Marcellus shale.

In 1841 (which was the second year of the association), Edward Hitchcock delivered the "First anniversary address before the Association of American Geologists in Philadelphia."[4] A few points are interesting in this historical sketch, as signifying the progress which geology had made in America up to this time.

[1] Am. Jour. Sci., vol. 39, p. 153. It is now (1890) called the Corniferous limestone.

[2] This limit is apparently the line between the Green sand and the Raritan clays.

[3] Geological Equivalents of the vicinity of New Albany, Indiana, as compared with those described in the Silurian system of Murchison; Proc. Phil. Acad. of Sci., vol. 1 1841, pp. 18, 19, 177, 178.

[4] See Am. Jour. Sci., *vol. 41, pp. 237-275.*

The Association[1] was formed the year before at the call of the gentlemen of the New York Survey, who "issued a circular inviting those engaged in similar surveys in other States" to a meeting in Philadelphia. We learn from Hitchcock's address that the first attempt to classify American geology was made by William MacClure in 1807, who, in the field work preparatory to this, crossed the Alleghany Mountains in fifty places. In 1810, Dr. Bruce had started the Mineralogical Journal; in 1816, Dr. Cleveland's Treatise on Mineralogy and Geology was published; in 1818, Silliman's Journal was begun; in 1818, also, an American Geological Society was founded at New Haven, with William MacClure as its first president. In 1832 the Pennsylvania Geological Society was started.

In addition to this general activity in the early part of the century, from the year 1824, when the first State survey was begun by Prof. Olmstead in North Carolina, up to the date of this address (1841), State surveys had been started and more or less publication had been accomplished in the way of reports or accounts of the surveys made in twenty-one States and Territories. The men engaged in these State surveys were as follows:

North Carolina, Olmsted; South Carolina, Vanuxem; Massashusetts, Hitchcock; Tennessee, Troost; Maryland, Ducatel; New Jersey, H. D. Rogers; New York, Vanuxem, Mather, Emmons, James Hall, Conrad, and Beck; Virginia, W. B. Rogers; Maine, Rhode Island, and New Hampshire, Jackson; Connecticut, Percival and Shepard; Pennsylvania, H. D. Rogers; Ohio, Mather, Hildreth, Locke, Briggs, and Foster; Delaware, Booth; Michigan, Houghton; Indiana, D. D. Owen; Kentucky, Mather (only a reconnaissance); Georgia, Cotting (no report had been published up to 1841); Arkansas, etc., Featherstonhaugh; Iowa, D. D. Owen and Locke.

Besides these, a reconnaissance had been made by Nicollet west of the Mississippi, and in 1824 Eaton's Erie Canal Survey had been made, and private surveys had been made by Taylor, Johnson, Silliman, and Shepard in coal and mineral regions in Pennsylvania, Virginia, and Missouri.

Hitchcock made slight reference to the actual state of progress in the matter of correlation and classification of the geological terranes; this can be better learned from the study of the New York reports, for the Paleozoic at least, and the other reports, which it is not necessary here to discuss.

The last annual report of the New York State Survey was published in 1841; sufficient to say here that the Archean was fairly well recognized along the eastern border of the continent, and its general extent

[1] The Association of American Geologists held its first meeting in Philadelphia on the 2d of April, 1840. The following were the original founders present at this meeting: E. Hitchcock, L. C. Beck, H. D. Rogers, L. Vanuxem, William W. Mather, W. R. Johnson, T. A. Conrad, E. Emmons, J. Hall, C. B. Trego, J. C. Booth, M. H. Boyl, R. E. Rogers, A. McKinley, C. B. Hayden, R. C. Taylor, D. Houghton, B. Hubbard.

E. Hitchcock was elected chairman and L. C. Beck secretary. See Am. Jour. Sci., vol. 39, p. 189.

rom Canada to the sources of the Mississippi. The Paleozoic was recognized in its distribution throughout the eastern part of the United tates. The Coal Measures were recognized in Pennsylvania, Ohio, ndiana, Illinois, Michigan, and Missouri. The Devonian was recognized by some of its fossils in New York State, but its limitation was ot determined precisely as at present. The Silurian had been recognized in at least the Caradoc sandstone, the Wenlock shale and limetone, and the Ludlow rocks, but it was not until the final reports were ublished (two or three years later) that a full classification of the 'aleozoic series was accessible to American geologists.

The Rogers brothers used fossils to determine the age of the Maitand limestone, and concluded that "though they indicate relation to)nondaga, Seneca, and Marcellus strata, the exact age is not proven." n other respects these authors adopted the New York classification as standard for comparisons.

The "Address before the Association of American Geologists and Iaturalists for the year 1842" was given by B. Silliman.[1]

In it we have a few indications of the state of the science at that ime. Silliman had the advantage of being in England in 1805, when he discussions of the rival schools, the Neptunists and the Vulcanists, he Wernerians and the Huttonians, were at their height; Prof. Jameon and Dr. John Murray defending the Wernerian views, and Sir ames Hall, Prof. Playfair, and Prof. Thomas Hope defending the iews of Hutton. Silliman appears to have taken a neutral position in egard to these schools, recognizing the good points of each. We find statement made in the course of his description of his part in the progess of science that Dr. Dana read the title of what was probably the rst geological report made on American geology, at the meeting of he Association in Boston, viz: "Beyträge zur mineralogischen Kentniss es östlichen Theils von Nordamerika und seiner Gebirge, von D. ohann David Schöpf."

Of William Maclure he said:

> He was the William Smith of this country, and not only did he add to the foreign ollections of this country in mineralogy and geology, but he did great service in the irection of personal field-work and interpretation of our geology, and also in pubshing his Geology of the United States with the first general map of the geology of he eastern part of the continent.

Mineralogy was studied prior to the cultivation of geology in America as well as in Great Britain. The earlier geologists were mineral eologists, and the collections of minerals constituted the principal abinets of that time. Prof. Cleaveland, of Bowdoin, Maine, Dr. Seyert, in Philadelphia, Colonel Gibbs, at Yale College, the Messrs. Dana, n Boston, had each accumulated more or less valuable mineral cabnets, and a Journal of Mineralogy and Geology was started in New

[1] Am. Jour. Sci., vol. 43, pp. 217 250.

York by Dr. A. Bruce, in 1809, which lasted a year, and in 1818 the American Journal of Science and Arts was established in New Haven.

Silliman did not rehearse any detailed account of the state of the science at the time, but gave general statements referring to the past, with comparisons of the general results effected by the American geologists with what had been done by the English and European geologists.

In 1842 T. A. Conrad published an important paper in the Journal of the Philadelphia Academy of Science, entitled "Observations on the Silurian and Devonian Systems of the United States, with descriptions of new organic remains." A number of fossils were identified, and several points of interest are noted in this paper, indicating the limitation of the groups as they were then recognized. The "older Paleozoic rocks" were the equivalent of the Transition of the older nomenclature. The author notes the perfection of the series of rocks in New York State, and "the great convenience they afford for study, in that they lie nearly horizontal."[1]

In this paper the "Cambrian rocks" are included in the Silurian, and the Silurian thus includes all the rocks from the Archean upward to the Tully limestone inclusive. Thus it will be seen that the fossils described previous to 1842 as Silurian fossils may have been Silurian or Devonian to the base of the upper Devonian.

A list of supposed equivalents is given,[2] in which we find the Lower Silurian strata are: "(10) Clinton group, (9) Niagara sandstone, (8) Shales of Salmon River,[3] (7) Blue shale, (5) Trenton limestone, (4) Mohawk limestone, (3) Birdseye limestone, (2) Calciferous limestone, (1) Potsdam limestone."[4]

The "Trenton limestone" is reported as "forming the bed of the Ohio River from Cincinnati to Louisville."

The Middle Silurian strata are the "Niagara shale, which equals the Wenlock shale, and upward to Oriskany sandstone.

The Upper Silurian rocks included the lower Ludlow and succeeding rocks upward to the Tully limestone inclusive.

In the Devonian system, Conrad placed as Lower Devonian the Ithaca group; as Middle Devonian, the Chemung group; as Upper Devonian, the Old Red sandstone.

The subdivision into Lower, Middle, and Upper Silurian appears to have been original with Conrad, and he proposed the names "Mohawk system" for the Lower, "Helderberg system" for the Middle, and "Onondaga system" for the Upper Silurian groups, respectively, and stated that the systems are based upon the "distinctness of the fossil contents."

The year 1843 marks one of the most important periods in the history

[1] Jour. Phil. Acad. Sci., 1842, pp. 228–235.

[2] *Ibid.* p. 230.

[3] *These three are regarded as the equivalents of the Caradoc.*

[4] *In his list there is no No. 6,* and Conrad states that 7, 5, 4, 3, 2, and 1 are wanting in Europe.

of American geology. The final reports of the State of New York were published in the years 1842–'43.[1]

The classification which appears in the several final reports was already outlined by Conrad in 1841, and, in fact, the general order of strata was given in his report for 1839. The development of the classification of the rocks for New York State will bear minute study, and will yield valuable suggestions to students of systematic geology. The rocks with which the New York geologists were concerned were mainly confined to the series from the Archean or Primary rocks through the Paleozoic as far as to the base of the Carboniferous. The geologists, although working together, had the State separated into four divisions and developed the stratigraphical geology of each district independently, observing the character of the individual rock formations, their order, and the fossils contained in each. Conrad was the paleontologist during the field operations, and his contribution to the work was the identification of the fossils sufficiently well to make recognizable the relationship between the fossils of the New York rocks and the formations of England which had been studied so carefully and were so elaborately defined by Murchison and Sedgwick.

The fossils of the British sections had been described by John Phillips, J. De C. Sowerby, and Lonsdale, and their descriptions were accessible to the American geologists as early as 1839. Conrad had used this Silurian system with its fossils as a basis for the classification and correlation of the rocks of New York State. The attempt was made in 1839 to divide the New York rocks in accordance with Murchison and Sedgwick's classifications, and the fossils found in them, corresponding with those of the British rocks, were enumerated. Thus, in the third annual report, Conrad gave a "table of formations," showing the order of superposition and some characteristic fossils of the Transition strata. The Carboniferous strata (No. 10) were mentioned (but are in Pennsylvania), then the rocks of New York[2] were distributed as follows:

Under the "Old Red sandstone group (Murchison)" he placed:

"9. Old Red sandstone (?) and Olive sandstone," which, we find from study of the reports, includes the Chemung and Catskill groups.

"8. Dark-colored shales and black slate," which appears to be the Hamilton and Marcellus.

Under "Medial Silurian system," are found "(7) Gray Brachiopodus sandstone, Helderberg sandstones, Helderberg limestones, second Pentamerus limestones; (6) Gypseous shales, Rochester shales, and Pentamerus limestones, (5) Green slate, Lenticular iron, etc., and (4) Niagara sandstone (red)."

[1] The editors of these final reports were William W. Mather, report of the first district, published 1843; Ebenezer Emmons, report of the second district, 1842; Lardner Vanuxem, report of the third district, 1842, James Hall, report of the fourth district, 1843. It is important also to remember that T. A. Conrad published his final report on the paleontology of the survey in the year 1841, in the fifth annual report.

[2] *N. Y. Geol. Survey, 3d Ann. Rep., pp. 62–63.*

Under "Lower Silurian system" he placed "(3) Salmon River sandstone (olive) and green slate, (2) gray Crinoidal limestone, Trenton limestone and slate, Mohawk limestone, gray limestone with sparry veins, gray Calcareous sandstone."

Under the term "Cambrian system (Sedgwick)" he placed "(1) olive sandstone and slate, and varigated sandstone (Potsdam sandstone of Emmons)," and below all these the "Primary."

In the next report[1] James Hall gave a somewhat more elaborate list of formations, but distributed them substantially as was done by Conrad. As this classification was only temporary, I will not stop to enumerate it in detail, the final results published in the final reports will be given in the proper place.

But in the fifth annual Report, Conrad produced a more finished classification, and with slight modifications the order of sequence of deposits and the general relations of the groups to each other are those which appeared in the several final reports; but we do not find the classification into the "divisions of the New York system" in Conrad's reports.

We may mention a few points in regard to Conrad's classification of 1841[2]. The following names were used: "Tertiary," "Cretaceous System," "Oolitic system," "New Red sandstone or Saliferous system," "Carboniferous system," "Old Red sandstone or Devonian system," including the Chemung and Catskill rocks. Then the "Upper Silurian series" included the rocks from the "Oneonta group, No. 26," to the "Black slate, No. 21." The "Middle Silurian series" included from the "Onondaga limestone, No. 20," down to the "Rochester shale, No. 10;" the "Lower Silurian series" included from "Pentamerus oblongus limestone, No. 9," to the "Potsdam sandstone, No. 1," inclusive.

Thus we see, that to the end of his work in connection with the survey Conrad's influence was directed toward the correlation of the American classification with that already in use in Great Britain.

After the annual reports were finished, the several geologists prepared their final reports. We find no evidence that Conrad assisted in their preparation, and in these reports, from the first one published to the last, there is a general symmetry in the classifications, but a neglect of any formal recognition of the classifications already adopted in Murchison's Silurian system, although the authors refer to the correlation of some of the New York deposits with recognized horizons in Murchison's Silurian system. A most important feature of the completed reports is the introduction of the "New York system" into geological nomenclature. The New York system was constituted to include the geological deposits from the earliest fossiliferous rocks to the base of the Carboniferous, and we find the four authors disagreeing in their interpretation of what this system included, and as to the groups into which it was subdivided.

[1] *Fourth annual report*, 1840. [2] See Fifth Annual Report, pp. 31-46.

Vanuxem and Mather adopted the following plan: They had a "Primary system," including the Archean as we consider it to-day; second, the "Taconic system," including a conglomeration of strata, all supposed by Emmons to lie below the Potsdam sandstone; third, the "New York system," which included the Champlain division, the Ontario division, the Helderberg division, the Erie division, and the Catskill division or group. Above this, according to Mather, followed the "Coal system," the "Red Sandstone system," the "Trappean system," the "Tertiary system," and the "Quaternary system," but Vanuxem enumerates only the last, the "Quaternary system," the others being wanting in New York State.

On the other hand, Emmons and Hall recognized the New York system as including the Champlain Ontario, Helderberg, and Erie divisions, but placed the rocks of the Catskill Mountains in a separate system, calling it the "Old Red system." The division line in their scheme between the New York system and the Old Red was at the top of the Chemung group.

When we inspect the local distribution of the several formations in the "divisions" of the New York system we find like differences of usage on the part of the several geologists. For instance, the Champlain group of Emmons and Hall terminates above in the Oneida Conglomerate, whereas in the reports of Vanuxem and Mather it terminates with the Hudson River group. In the Ontario group Mather includes only the Oneida Conglomerate; Emmons includes the strata from the Medina to the waterlime; Vanuxem, those from the Oneida to the Niagara; and Hall, those from the Medina to the Niagara, inclusive. The Helderberg division was regarded by Mather, Vanuxem, and Hall as extending from the Onondaga salt group through the Corniferous limestone, while Emmons made it begin with the Pentamerus limestone and carried it to the top of the Helderberg limestone. All four of the geologists in their final reports agree in the limitation of the Erie division, including the rocks from the Marcellus shales through the Chemung group.

Another point may be mentioned: While individual formations are substantially alike as named by the several reporters, there are frequent differences in usage, as in the use of "Loraine shales" by Emmons for the Hudson River group of the other reports, and of "Corniferous limestone" by all the authors but Emmons, who uses "Helderberg limestone." Besides these differences we notice that deposits are mentioned in some of the reports which are left out in others, and in some reports the name of the rock is given, while in others the word "group" is attached to a geographical name, as "Niagara limestone" and "Niagara group."

These differences which appeared in the final reports accentuate the difficulties which the geologists met with in attempting to classify the rock formations according to the methods then in use. The old sys-

tem of correlation by means of the petrographic characters of the deposits was used in part by these geologists and formed the original basis of the classification. In the field work the formations were distinguished by their petrographic features and were so defined. In most cases local names were applied to them; the geographic designation of the place where the particular formation was discovered, or was found to be exposed in a good condition, was applied to the rock, and as the surveys went on the name as applied was extended to the other outcrops of what appeared to be the same stratum or series of strata. This was all very well so long as no correlation was attempted, but as soon as correlation of the several formations with those of other regions was attempted the necessity of some other means of identification was apparent. This means was recognized in the fossil contents, but in the field the fossils were not studied, and could not be studied by the field geologists. It was necessary to take them home and compare them with other fossils from other parts of the country and world, and to describe them, and ascertain their range and distribution. All this required time and learning, which could not be attained at once by any one of the geologists. This learning was the special province of the paleontologist, and the wide knowledge requisite to correlate the various strata of the New York system accurately with those of Great Britain was, we may imagine, clearly recognized by Conrad before he left the survey; but, as we have learned since, many years of study have not enabled geologists to establish with certainty the correlation between the several faunas of the formations in New York and those abroad.

The great desideratum at that time, and for geologists at the present time, is such a system of nomenclature and classification as shall enable the field geologist at once to record his observations correctly and systematically, and to preserve the records of fossil contents which he discovers for the careful detailed study of the paleontologist. The nomenclature adopted in many cases by the New York geologists, which has satisfied the demands of the progress of science, at least up to the present time, is that which is based upon the simple practice of giving a geographic name to a rock terrane, connecting it with the name of the particular rock which is exhibited at the locality in which it outcrops; for example, "Trenton limestone," "Oriskany sandstone," "Schoharie grit," "Genesee slate," although in the latter case slate is not appropriate, because it is a false name, shale being the right name. These several terms applied to definite rock masses located in particular regions in New York State, having their typical outcrops designated by their names, can be applied with exactness at all times, and suggest the progress of the science. Whenever wrongly applied to deposits outside the original region where discovered, new names can be easily substituted.

The groupings of these separate formations, made without regard to

the fossils characterizing them, were purely arbitrary, and were ultimately discarded. We have already entirely ignored the "New York system," the "Champlain," "Ontario," etc., "divisions," and the only part of the New York classification which is retained, is the nomenclature of the individual formations in their stratigraphic sequence. It is evident, therefore, considering how important the work of this New York survey has been for all American geology, that the most important part of the work of the geologist is that of carefully observing the characters of the individual formation, describing its petrographic, stratigraphic, and geologic relations, preserving the fossils accumulated, and describing his observations so that distinct association will be found in the name applied to each formation with the observations actually made in the field. The reference of each particular formation to a place in some standard scale should not be made without careful study. This careful study can not be made independently of the fossils, for fossiliferous rocks, and in order that the paleontologist may make his studies without prejudice, the names of the formations, their localities, and their petrographic characters should be described and recorded, quite independently of the fossils which they contain.

The following tables will exhibit the final results of the four State geologists in their attempts to classify the geological formations of the State of New York.

They are taken from the final reports of the "Geology of New York," and are arranged in the order given them by the authors.

CLASSIFICATION BY MATHER. 1843.

[Final Report, First District, p. 2.]

1. Quaternary system. { Alluvial division. / Quaternary division. / Drift division.
2. Tertiary system.
3. Trappean system.
4. Red Sandstone system.
5. Coal system.
6. New York system .. { Catskill division. / Erie division. / Helderberg division .. { Corniferous limestone, Onondaga limestone, Schoharie grit, Canda-Galli grit, Oriskany sandstone, Catskill shaly limestone, Pentamerus limestone, Water lime group, Onondaga salt group. / Ontario division..... Oneida or Shawangunk Conglomerate. / Champlain division... { Hudson River group, Utica slate, Trenton limestone, Calciferous group, Potsdam sandstone.
7. Taconic system.
8. Primary system]... { Metamorphic rocks. / Primary rocks.

CLASSIFICATION BY EMMONS. 1842.

[Final Report, Second District, p. 428.]

Tabular view of the sedimentary rocks of New York.

Taconic system		Taconic slate, Magnesian slate, Stockbridge limestone, Granular quartz.
New York system.	Champlain group	Potsdam sandstone, Calciferous sandrock, Chazy and Birdseye limestone, marble of Isle La Motte, Trenton limestone, Utica slate, Lorraine shales, Gray sandstone, Conglomerate.
	Ontario group	Medina sandstone, Green shales and Oolitic iron ore, Niagara limestone, Red shale, Onondaga salt and plaster rocks, Manlius water-lime.
	Helderberg series	Pentamerus limestone, Delthyris shaly limestone, Oriskany sandstone, Encrinal limestone, Cauda-Galli grit, Schoharie grit, Helderberg limestone.
	Erie group	Marcellus and Hamilton shales, Tully limestone, Genesee slate, Ithaca and Chemung shales and grits.
Old Red system		Old Red sandstone, with its beds of Conglomerate and its greenish shales of the Catskill Mountains.
New Red system		New Red sandstone associated with volcanic rocks and greenstone trap of the Palisades.
Tertiary		Blue and yellowish clays of Champlain and white and yellowish sand.

CLASSIFICATION BY VANUXEM. 1842.

[Final Report on the Third District, p. 13.]

Classification of rocks of New York State.

1. Primary system.
2. Taconic system.
3. New York system

Champlain division	Potsdam sandstone, Calciferous group, Black River limestone, Trenton limestone, Utica slate, Hudson River group.
Ontario division	Gray sandstone, Medina sandstone, Oneida Conglomerate, Clinton group, Niagara group.
Helderberg division	Onondaga salt group, Water-lime group, Pentamerus limestone, Catskill shaly limestone, Oriskany sandstone, Cauda-Galli grit, Schoharie grit, Onondaga limestone, Corniferous limestone.
Erie division	Marcellus shale, Hamilton group, Tully limestone, Genesee slate, Portage group, Ithaca group, Chemung group.
Catskill group.	

4. Quaternary system.

CLASSIFICATION BY JAMES HALL.[1] 1843.

[Final Report, Fourth District, pp. 18, 19.]

Tabular view of rocks and groups of New York.

I. Primary or Hypogene system.

II. Taconic system.

III. New York system ....

- Champlain division..
  1. Potsdam sandstone.
  2. Calciferous sandrock.
  3. Black River limestone group, embracing the Chazy and Birdseye.
  4. Trenton limestone.
  5. Utica slate.
  6. Hudson River group.
  7. Gray sandstone.
  8. Oneida or Shawangunk Conglomerate.
- Ontario division.....
  9. Medina sandstone.
  10. Clinton group.
  11. Niagara group, including shale and limestone.
- Helderberg series....
  12. Onondaga salt group.
  13. Water-lime group.
  14. Pentamerus limestone.
  15. Delthyris shaly limestone.
  16. Encrinal limestone.
  17. Upper Pentamerus limestone.
  18. Oriskany sandstone.
  19. Canda-Galli grit.
  20. Schoharie grit.
  21. Onondaga limestone.
  22. Corniferous limestone.
- Erie division .....
  23. Marcellus shale.
  24. Hamilton group. (Moscow shales, Encrinal limestone, Ludlowville shales.)
  25. Tully limestone.
  26. Genesee slate.
  27. Portage or Nunda group. (Portage sandstone, Gardeau flagstone, Cashaqua slate.)
  28. Chemung group.

IV. Old Red system, or Old Red sandstone.

V. Carboniferous system.

VI. New Red sandstone.

VII. Tertiary.

VIII. Quaternary system.

RÉSUMÉ OF CLASSIFICATIONS.

Champlain group ...Emmons and Hall agree in terminating it with the Oneida Conglomerate.

Vanuxem and Mather terminate it with the Hudson River group.

Ontario group .....Emmons, Medina to Water-lime, inclusive.

Hall, Medina to Niagara, inclusive.

Mather, Oneida Conglomerate alone.

Vanuxem, Oneida to Niagara (but order wrong).

Helderberg series....Emmons, Pentamerus limestone to Helderberg limestone.

Hall, Onondaga salt group through Corniferous limestone.

Vanuxem, Onondaga to Corniferous.

Mather, Onondaga to Corniferous.

Erie division.....Marcellus to Chemung, inclusive, by all.

---

[1] According to this author the formations 1, 2, 3, 4 were correlated with the "Cambrian system" of Sedgwick, the Potsdam (1) doubtfully included. "Silurian system" Murchison=Utica slate (5) to Hamilton (24). "Devonian System" of *Phillips*=Chemung and Portage and part of the Hamilton (24 to 28). (See p. 20.)

CHAPTER II.

THE GENERAL APPLICATION OF THE NOMENCLATURE OF THE NEW YORK SYSTEM AS A STANDARD OF CORRELATION IN OTHER PARTS OF THE UNITED STATES. 1840 TO 1851.

The termination of the New York State Survey and the publication of the final reports practically established the new ideals for the classification of the Paleozoic rocks of North America.

The Final Report on the Geology of the Fourth District (the western quarter of the State) by James Hall was published in 1843. This may be regarded as expressing the more perfected views in regard to classification and nomenclature.

The New York system was the comprehensive term applied to the series of rocks beginning with the Potsdam sandstone and terminating in the "Chemung group." The rocks of the Catskill Stage were called the Old Red system or Old Red sandstone. The New York system was made up of twenty-nine "systematic subdivisions," "founded upon the fossil and lithological characters."[1]

These were grouped into four "geographical subdivisions." The lowest, from the Potsdam to the Oneida Conglomerate, inclusive, was named the "Champlain Division;" the second, including the Medina, the Clinton, and the Niagara, was called the "Ontario Division." From the Onondaga Salt group to the Corniferous limestone, inclusive, was the "Helderberg series." From the Marcellus to the Chemung, inclusive, was the "Erie Division."

Comparisons had been made with the Silurian system of Murchison and the Devonian of Murchison and Phillips, and a general correlation recognized, but the equivalencies were not minutely accordant.

In respect of the part of the scale with which this essay is concerned, the author wrote, "If the Devonian is to be regarded as a distinct system, we shall find its repesentatives in the Chemung and Portage groups, with perhaps a part of the Hamilton group. In New York, however, as already stated, no subdivisions can be made which are entitled to the name of systems."[2]

[1] (No. 3 of p. 18 was expanded into two subdivisions on p. 517 (i. e., Nos. 27, 26) by the recognition of the Chazy limestone as distinct from the Black River limestone.)

[2] Geology of New York, part IV, comprising the survey of the fourth geological district, by James Hall, 1843, p. 516.

In the table the following equivalencies are given:[1]

Rocks of the New York system.	Subdivisions in Great Britain.
Old Red sandstone	Old Red sandstone.
1. Chemung group	Upper and Lower Ludlow rocks including the Devonian system of Phillips.
2. Portage group	
3. Genesee slate	
4. Tully limestone	
5. Hamilton group	
6. Marcellus shale	
7. Corniferous limestone	Wenlock rocks.
8. Onondaga limestone	
9. Schoharie grit	
10. Cauda-galli grit	
11. Oriskany sandstone	
12. Upper Pentamerus limestone	
13. Encrinal limestone	
14. Delthyris shaly limestone	
15. Pentamerus limestone	
16. Water-lime group	
17. Onondaga salt group	
18. Niagara group	

Correlations with the Pennsylvania and Virginia rocks and those of Ohio and Michigan are expressed as follows:

Pennsylvania and Virginia Survey.	Ohio Survey.	Michigan Survey.
28. Chemung group 27. Portage group — No. 9	Waverly sandstone series.	Soft light-colored sandstones, argillaceous slates and flagstones of Lake Huron, sandstones of Point aux Barques.
26. Genesee slate — No. 8	Wanting(?)	
25. Tully limestone	Wanting	
4. Hamilton group — No. 8	Wanting or but partially developed.	Shales, black aluminous shales.
23. Marcellus shale — No. 8	Black slate.	
22. Corniferous limestone	Upper part of Cliff limestone.	Corniferous limestone.
21. Onondaga limestone		
20. Schoharie grit		
19. Cauda-galli grit — No. 7		Several limestones represent this and lower beds.
18. Oriskany sandstone — No. 7		

Some of the results thus far attained were permanently satisfactory; others have already been modified, and there are still others which await correction.

The classification of the rocks of the New York system into "systematic subdivisions, founded upon the fossil and lithological characters," and the application to them of geographical names suggested by the locality where the typical sections occur have stood the test of common use for 50 years. The classification is based upon observed facts, and the nomenclature is expressive of actual facts with no mixture of theory.

The groupings of these stages into "geographical subdivisions" is faulty, in that it expresses only accidental relations, and produces purely artificial groups. There are no geological reasons for drawing

[1] Geology of New York, part iv, comprising the survey of the fourth geological district, by James Hall, 1843, p. 517.

[2] Ibid., p. 619.

the lines between the "Champlain" and "Ontario," or the "Ontario" and "Helderberg divisions," and this part of the classification has accordingly fallen out of use, because useless.

Like objection exists to the term "New York system." While the base is well marked, the rocks of Pennsylvania, to the top of the Coal-Measures, should be added to them to complete the system. Adding the Carboniferous system, as expressed in Pennsylvania, Ohio, and Virginia, a natural group of the first order is produced which nearly corresponds to what we call the Paleozoic era. Were we to adopt for this grand terrane the name *Appalachian group*, we should have a properly constituted name for an actual, existing geologic group, free from theory, and its use would probably assist in the progress of science.

This classification of the New York State survey is further defective in the retention from the old nomenclature of such definitive terms as Corniferous, Encrinal, Water-lime, etc. Intrinsically they are not distinctive of any particular stage and therefore do not fulfill the true purpose of names for the stages.

A similar objection holds in the case of such names as Cauda-galli grit, Pentamerus limestone, and similar terms. Although the fossils indicated may characterize the formations so named in their typical outcrops, the fossils may fail in the geographic extension of the formation, or further study may show that the fossils are not confined stratigraphically to the zone represented by the particular formation in question.

The only kind of name which can be applied without objection to the ultimate subdivisions of the terranes, is a binomial term composed of the lithologic name of the rock and the geographic name indicating its typical exposure.

The use or the name "Old Red sandstone system" has been discarded, and its use in 1843 indicated that the name *system* gave such dignity to a terrane that it was supposed necessary to find it in every complete section of rocks. It was later that geologists agreed that the Old Red sandstone represents the Devonian system, but represents it in a different type of deposits.

The imperfection in the nomenclature, even at the present time, is seen in the fact that English geologists[1] still use the phrase "Devonian and Old Red sandstone" for the rocks between the Silurian and Carboniferous systems. This error and confusion comes from the difficulty in ridding ourselves of the old notion that the *age* of rocks may be indicated by their lithologic or stratigraphic characters. Age can be indicated only by something which persists through time; the lithologic characters of rocks indicate what they were made of and how; the stratigraphy indicates the order of sequence. The age of rocks can be indicated only by something which changes with the passage of time according to some definite law. The organisms represented by

[1] *1887. Geikie* Text-Book: Woodward's Geology of England and Wales.

fossil remains alone meet these requirements. A continuous rock section furnishes us with the order of sequence of these changes, but a classification of the rocks based upon the age of the fossils must not be hampered by stratigraphic or lithologic limits. The time classification can be built up only gradually by wide study of the fossils, and the nomenclature of the formations must be applied, and applied with precision, before the time limitations can possibly be fixed with precision.

Besides these defects in the final results of the New York survey, there were two imperfections occasioned by lack of evidenc, and others due to false generalization. The Devonian system was scarcely more than recognized by its general fauna—the limits above and below were not determined. The upper limit excluded the Catskill formations which were subsequently placed in the system. An equivalency was supposed to exist in Ohio and Michigan between the Chemung and the rocks now called Waverly belonging in the Carboniferous system. The attempts to correlate with the English models resulted in fixing the limit between the Wenlock and lower Ludlow of Murchison between the Corniferous limestone and Marcellus shale of the New York system. The rocks above this limit were correlated with Murchison's Ludlow group and Phillips's Devonian system.

The imperfection of this work was mainly due to ignorance of the precise relations existing between the two faunas; and, secondly, to the fact that Phillips's fossils were mainly middle and upper Devonian forms, while the lower Devonian species and the lower Devonian type of deposits were not well understood by the New York geologists.

It was the comparative study of the fossils, and particularly a more careful discrimination of them and better appreciation of the range of the characters they exhibited, which finally cleared up these imperfections.

Having perfected a scheme of classification, the next step of progress was the correlation of the formations west of New York with the scheme. This was mainly accomplished during the decade from 1840 to 1850. The chief discussions of the subject were published between 1842 and 1851.

James Hall published an article in 1842[1] in which an attempt was made to correlate the rocks of the States of Ohio, Indiana, Illinois, part of Michigan, Kentucky, Missouri, Iowa, and Wisconsin, with the rocks of New York State. He classified the basins of the Coal Measures into four groups, as follows: first, that of Pennsylvania and eastern Ohio; a second extending over portions of Indiana, Illinois, Kentucky, and Tennessee; a third in Missouri, and a fourth in Michigan. He traced the underlying "conglomerate" from Pennsylvania to the Mississippi River. The "Old Red sandstone" was not recognized west of the Genesee River in Allegany County, New York; the Chemung formation, which, he remarked, "Lyell compares with the lower part of the

[1] *Notes upon the Geology of the Western States*, Am. Jour. Sci., vol. 42, p. 312.

Old Red in Forfarshire, etc., Scotland, in its gray, thin, laminated sandstones and green shales," Hall recognized in Ohio, at Cuyahoga Falls, Akron, etc. He also correlated the Portage and Gardeau with rocks at Cuyahoga Falls and Newburg in Ohio, but found them of diminished thickness. He said, "The Portage sandstone (known as Waverly sandstone)" is found in many places in Ohio. The thin-bedded limestones which he found often Oolitic in structure, and in some places becoming thick beds of limestone interstratified with sandstone, in Indiana, Illinois, and Kentucky, Hall found to contain fossils which were different from those of the limestones of New York, and he thought them to be identical with the Carboniferous limestone of Europe, recording one of the fossils, *Productus hemispherica*, which was a characteristic of that formation.[1] The conglomerates which occur above this he correlated with the Millstone grit of the British classification. This identification of the carboniferous rocks in the West, or in the Mississippi Valley Basin, was not new with Hall, but had been made several years before by D. D. Owen, as will be shown further on.

In 1842 Hall[2] read a paper before the Association of Geologists and Naturalists, which was published the following year with a plate explaining a section from Cleveland to the Mississippi River. In this plate the Waverly sandstone series of the Ohio report is called "Chemung and Portage groups." The term "Subcarboniferous rocks" is applied to "friable gray sandstone with intercalated beds of oolitic limestone" lying between the "Waverly series" and the "Carboniferous limestone." Where the latter outcrops in the Mississippi River Valley it is called the "Great Carboniferous limestone."

At Newburg "the Portage sandstone or upper part of the group is seen, and is there underlaid by the green shale. These are equivalent to the Waverly sandstone of the Ohio reports, as was afterward ascertained by visiting the quarries at Waverly. From Newburg we pass over the shales and sandstones of the Chemung group, till we arrive upon the Conglomerate, which is well developed at Stow and Cuyahoga Falls. This Conglomerate, which, so far as I could discover, is identical with the outlier of a similar mass in the southern part of New York, is the fundamental rock of the great coal formations."

The "black, bituminous shale underlies this Portage and Chemung on the road toward Columbus, and represents Hamilton and Marcellus, particularly the latter."[3]

In the vicinity of Louisville and New Albany, at the Falls of Ohio, the "black, bituminous limestone" he correlated with the Marcellus shale of New York above the "Corniferous limestone." This is followed by the "green shales and slaty sandstones of the Portage group

[1] Notes upon the Geology of the Western States, Am. Jour. Sci., vol. 42, p. 57.

[2] Hall, James: Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a *southwest direction*, with remarks upon the identity of the western formations with those of New York. *Assoc. Am. Geol.*, Trans., 1843, pp. 474 531.

[3] *Ibid.*, p. 272.

or Waverly sandstone series of Ohio."[1] Above this were seen "friable gray sandstones with intercalated beds of oolitic limestone."

"These rocks are marked in the section by the name '*Subcarboniferous*,' and although the fossils and the character of the intercalated beds of limestone indicate the commencement of the same era as the Carboniferous limestone, yet it requires that a limit should be fixed between what is to be strictly referred to Carboniferous and older deposits."[2]

In a foot-note the author referred to Dr. Owen's denomination of "the rocks here described as well as the succeeding limestone as Subcarboniferous," and remarks that he had not seen the report when his section was prepared.

D. D. Owen first applied the term *Subcarboniferous* to the limestones underlying the Coal Measures, having included with them the Silurian limestones, and to the whole series he applied the designation *Cliff limestone*. James Hall introduced the name *Subcarboniferous* to indicate rocks which he regarded as lying below the "Carboniferous limestone," the intercalated calcareous beds of which contained fossils like those of the Carboniferous era.[3]

The "Carboniferous limestone" of Hall's paper was not recognized east of New Albany, Indiana, where it is reported as resting upon the "Subcarboniferous rocks." From there it was traced westward, and along the Mississippi Valley in Illinois, Iowa, Missouri, and Tennessee.

The author held that upon going westward the character of the deposits changes, and the nature of the species changes with indications of difference in depth.

It will be seen that Hall's interpretation was based upon tracing the continuity of the strata. Though fossils were considered in a general way, the differences noted were regarded as due to changed conditions rather than to lapse of time. So that the more minute comparison of the fossils for a long time failed to convince geologists of the errors of correlation.

The misinterpretation of the relation of the Waverly formation of Ohio to the New York system was very difficult to correct, since the State geologist who best knew the New York system had claimed, as the result of personal examination, tracing the rocks step by step all the way from New York to the Mississippi Valley, that these rocks were identical. It was difficult to get people to believe in the testimony of fossils against such assertions.

In the year 1843 H. D. Rogers[4] expressed the opinion that the black bituminous shales which appear in the States west of Ohio, between the Silurian and the Carboniferous, represent the Marcellus shales of New York State, and in this opinion he differed with Hall, who re-

[1] Hall, James: Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a southward direction, with remarks upon the identity of the western formations with those of New York. Assoc. Am. Geol., Trans. 1843, p. 280.

[2] Ibid., p. 281.

[3] See Chapter VIII.

[4] Rogers, Henry D.: On Marcellus and Hamilton of the West. Am. J. Sci., vol. 45, 1843, pp. 161, 162.

garded them as representing both the Marcellus and the Hamilton, although not equivalent to either.[1]

In 1843[2] David Dale Owen commented "On the Geology of the Western States." In this paper a fine-grained sandstone and chert with iron ore was described from Tennessee, Kentucky, and Indiana, and examined on its outcrop near the Knobs. In its lower part this formation was correlated with the Devonian system of England and with the Chemung group of New York, and was described as resting on black bituminous shales and as equivalent to the Marcellus shales of New York.

The high appreciation of the results of the New York State survey is indicated by the frequent references which were made in the Journals to the reports.[3]

In D. D. Owen's review a tentative scheme of a chronologic table is given as follows:[4]

Protozoic rocks or New York system.

Transition series		1. Potsdam sandstone.
First or Lower Division		2. Calciferous sandrock.
		3. Black River limestone.
		4. Trenton limestone.
		5. Utica slate.
		6. Hudson River group.
Transition series		7. Oneida Conglomerate.
		8. Medina sandstone.
		9. Clinton group.
Second or Middle Division		10. Niagara sandstone.
		11. Onondaga Salt group.
		12. Water limestone.
		13. Pentamerus limestone and Catskill shaly limestone.
		14. Oriskany sandstone.
Transition series		15. Cauda-galli and Schoharie grit.
		16. Onondaga limestone.
		17. Corniferous limestone.
Third or upper division		18. Marcellus shale.
		19. Hamilton group.
		20. Genesee slate.
		21. Portage group.
Transition series		22. Chemung group.

Owen speaks of the Marcellus shale as "the base of the third division of the American Protozoic rocks." The equivalents to this are given as the "lower part of F. VIII of Pennsylvania and Virginia, Postmedidial, Older Black slate of Rogers."[5] The transition from the underlying Corniferous and Seneca limestone is sharp.

He expressed the opinion that the black shale at the Falls of Ohio is probably the representative of the Genesee, and that the Encrinital limestone of Tennessee and Kentucky (Button Mould Knob) may represent the Encrinital limestone of the Hamilton of New York.[6]

---

[1] See Am. Jour. Sci., vol. 43, pp. 161 162.

[2] Am. Jour. Sci., vol. 45, pp. 151 165.

[3] Among these may be mentioned particularly, "Review of the New York Geological Reports," by D. D. Owen, published in the Am. Jour. Sci., vol. 46, pp. 143 157; vol. 47, pp. 354 380; vol. 48, pp. 296–316; 2d ser., vol. 1, pp. 43 70, vol. 3, pp. 164 171.

[4] *Ibid., vol. 47, p. 355.* (This article is signed "D. D. O.," p. 380.)

[5] *Am. Jour. Sci., vol. 3, 1847, p. 57.*

[6] *Ibid, p. 72.*

In 1844 Henry D. Rogers delivered the annual address before the association of geologists and naturalists at the meeting held in Washington, May, 1844.

At that time the geological publications of the United States had reached a stage of considerable perfection, the author remarked.[1] The "Geology and Mineralogy of the State of New York" had been issued. Reports on surveys covering the greater part of the Eastern States of the Union had been published, furnishing information in regard to the Paleozoic, Mesozoic, and Tertiary formations of this half of the United States. In regard to the Paleozoic formations he said:

> From Lake Champlain, therefore, westward to the mouth of the Wisconsin River, a distance of at least 1,100 miles, and southward to Alabama, over a still larger and very complicated tract, and throughout the entire triangular area included between these limits, the boundaries of each of our Paleozoic Appalachian formations have been determined and with very considerable precision.[2]

He and his brother had prepared a map of the United States, 14 feet by 12 feet in size. This was apparently of the eastern part of the United States.[3]

The paleontology of the Appalachian basin at this time had been carried on by the researches of Messrs. Conrad, Emmons, and Hall, in New York, and by Messrs. Hall, Owen, Troost, Locke, and Clapp, in the Western States, until "five hundred well characterized marine fossils had been made known." The work of study and description was pushed further, particularly by James Hall. Rogers acknowledged, in 1844, that "the most elaborate classification of our Appalachian Paleozoic strata hitherto is that of the New York geological survey." "It embraces, under the title of the New York system, the entire body of strata from the bottom of the lowest fossiliferous rocks to the base of the Red sandstone of the Catskill Mountains."

Although the New York geologists were acknowledged to have provided a valuable classification of these formations, the author did not feel satisfied with recommending this for general adoption. He appreciated the difficulties attaching to the application of local names to the geological formations, and because of the necessity of a general nomenclature for rocks he gave an account in this address of a scheme of grouping and naming the Paleozoic strata, which his brother, W. B. Rogers, and himself had been maturing during the last three years.[4] Their nomenclature was purely artificial. To quote he says:

> We propose to distribute the whole great body of strata, from the base already designated to the top of the Coal Measures, in *nine* distinct *series*, the products of as many great successive *periods*, and resorting to the analogy between these periods and the nine natural intervals into which the day is conveniently divided we have named them in ascending order, the *Primal*, the *Matinal*, *Levant*, *Preme-*

[1] Rogers, Henry D., on American geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, pp. 137-161, 247, 278.

[2] Ibid, p. 146.

[3] See p. 147. I find no evidence that it was published.—H. S. W.

[4] Ibid, p. 154.

didial, Medidial, Post-medidial, Ponent, Vesperine, Seral series; the deposits of the Dawn, Morning, Sunrise, Forenoon, Noon, Afternoon, Sunset, Evening, and Twilight periods of the great Appalachian Paleozoic day.

The author goes to some length in explaining the application of this scheme to the formations of the "Appalachian system" and their corresponding limits in the formations of the New York geologists, and we notice that he has attempted to cover very much the same field already covered by the nomenclature of the New York State survey. The advantages of his nomenclature it seems to the writer are entirely negative; the names are entirely arbitrary, and on that account have not the objections attaching to them which were raised against mineralogic or paleontologic names. The greatest objection to the scheme as a whole is that it is necessarily local, both geologically and geographically, since it is a scheme of nomenclature which does not permit intercalations without disturbing its symmetry, and it does not allow of expansion to cover what might be found below or to cover the higher rocks.

The author discussed in the latter part of his address the formations of the Mesozoic period, named the Red sandstone along the eastern border "Mesozoic Red sandstone,"[1] and enumerated some of the fossils occurring in the "Mesozoic Coal Measures of Eastern Virginia." The Cretaceous deposits are briefly referred to and a few of their characteristic fossils enumerated. The Cainozoic or Tertiary period is also briefly described, and above that the Post-Pliocene period is reported in Maryland and North Carolina and elsewhere along the coast, and a few of the fossils which Conrad had been so active in describing are named.

In 1847 Daniel Sharp[2] reported the Oriskany sandstone, Cauda-Galli grit, and Schoharie grit as locally distributed in New York, the first being most prominent in Pennsylvania and Virginia. The whole series is classified in the Devonian system.

The Marcellus shale, the Hamilton group (Moscow shales, Encrinal limestone, Ludlowville shales), Tully limestone, and Genesee slate are especially distinguished by their faunas, which consist chiefly of Brachiopods and Lamellibranchs, the majority of them peculiar to the Devonian while a few occur in the higher Carboniferous deposits. This is by far the most fossiliferous series in the Devonian system. The Portage group, consisting of sandstones and shales and having a thickness of 1,000 feet, is nearly barren of fossils, while the Chemung rocks, which have a thickness of 1,500 feet and occur just above the Portage group, are highly fossiliferous. Both of these series are considered as belonging to the Devonian system, and with the Hamilton group constitute the "Erie division." The Devonian system closes with the Chemung group, above which comes the Old Red sandstone formation.

[1] Am. Jour. Sci., vol. 47, 1844, p. 247.

[2] Sharpe, Daniel: Report on the fossil remains of mollusca from the Paleozoic formations of the *United States (etc.)*, with remarks on the comparison of the North American formations with those of *Europe*. *Quart. Jour. Geol. Soc.*, 1847, vol. 4, pp. 145–161.

The author in the main agreed with American geologists in the line of division between these two great groups of rocks. He then correlated the system of America with that of Europe, after which he added a tabulation of the faunas of both countries, giving references to synonyms, strata, localities, and formation in country.

In 1848, before the American Association of Geologists and Naturalists, James Hall presented a paper[1] in which some valuable comparisons are given of the characters expressed by the rocks as they outcrop in different areas. The Hudson River group was recognized in Ohio, Indiana, Kentucky, and elsewhere in the interior. It becomes more calcareous and is called "Blue limestone" in the more western exposures. Hall noticed that it contains Conchifera in the East with few Brachiopods; that in the West, Brachiopods are conspicuous with Corals and Crinoids, Crustacea, and Trilobites. The Oneida conglomerate, the Medina sandstone, and the Clinton formations of New York were very slightly represented in the Southwest. The Niagara shale and limestone in the East were both fossiliferous; in their western exposures the limestone is reported as thicker and containing abundant Corals, and the calcareous matter is reported as increasing on coming westward. The Onondaga Salt formation thins out on coming westward, the Helderberg formations mainly disappear west of New York, except the Upper Limestone, which appears in Ohio, Indiana, and Kentucky, but is of lighter color than its representatives[2] in New York. The Marcellus and the Hamilton formations are reported as sandy in the East, and the muds diminish and the sands increase in western New York, and in Ohio only the lower, Shale, and this of limited thickness appears. The rocks from the Hamilton group upward, and the Old Red sandstone are more sandy in the East, and more argillaceous and thinner westward. The rocks of the Catskill Mountains, called the "Old Red sandstone," also appear in eastern Pennsylvania, but disappear westward, allowing the Coal Measures to rest on the conglomerate in the East, but in the West, on the Chemung, and still farther west on the limestone.

As a conclusion from these observations the author pointed out that a continent supplying sediments must have existed eastward of the great deposition of sediment along the border, extending from New York through Pennsylvania southward.

M. Ed. de Verneuil, after a visit to the United States and examination of our formations and their fossils, published in the Bulletin of the Geological Society of France the most valuable paper on correlation which had appeared up to this time.[3]

---

[1] The Geographical Distribution of Fossils in the Older Rocks of the United States.

[2] The Corniferous and Onondaga limestone.—H. S. W.

[3] Note sur le parallélisme des roches des dépôts paléozoïques de l'Amérique septentrionale avec ceux de l'Europe, suivie d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des Étages où elles se rencontrent et terminé par un examen critique de chacune de ces espèces. Soc. géol. France, Bull., 2e sér., vol. 4, 1847, pp. 646–709.

A few copies of the paper doubtless came to America, but the form in which it had most effect upon American geology was the condensed translation and review of it by Mr. James Hall, which appeared in the American Journal of Science.[1]

In the present essay the original paper and Hall's comments upon it will be discussed together.

Mr. Hall's Review of M. de Verneuil's Study of the American Paleozoic was entitled "On the Parallelism of the Paleozoic Deposits of North America, with those of Europe; followed by a Table of the Species of Fossils common to the two Continents, with indication of the positions in which they occur, and terminated by a critical examination of each of these species; by Ed. de Verneuil (translated and condensed from Bulletin of the Geol. Soc. of France, 2d ser., vol. 4 for this Journal; by James Hall, New York State Geologist)."

This review is of great importance historically, as it shows how the classification of the New York strata was perfected by comparisons with the European strata and their fossils.

M. de Verneuil, one of the ablest paleontologists of the time, had been associated with Murchison in studying the Russian series. This had led to a careful comparison of the English Silurian and higher rocks with those of Russia, and had fitted him preeminently to recognize corresponding species, zones, and faunas in the New York and American series. And this "review" of his report on the "parallelism" was by the rising paleontologist of New York, who, better than any other American, understood the fossils and the arguments presented.

De Verneuil appreciated the great value, for classificatory purposes, of the New York series. He said, "No country in Europe offers us so complete and uninterrupted a development of the Silurian and Devonian systems," and "this series presents a continuous succession of deposits which are superimposed in regular stratification."[2]

The various strata of this New York system had been defined and named in their stratigraphic order, each different kind of rock receiving a distinct, generally geographic name. These formations had been grouped together arbitrarily on grounds of their geographic outcrops; as Champlain, Ontario, Helderberg, and Erie divisions. By some of the State Geologists they were regarded as merely convenient groupings of the rocks for reference, and of no scientific value.

In the final reports attempts had been made to correlate them with the English subdivisions, as given by Murchison and others, but these correlations were incorrect, as the result has shown.

No satisfactory method of classifying the individual formations into more comprehensive groups had been attained. De Verneuil proposed to unite them into groups according to their paleontologic affinities.

[1] *Second series, vols. 5 and 7, 1848.* [2] Am. Jour. Sci., 2d ser., vol. 5, p. 178.

This had been roughly attempted by Hall, but, as we examine the changes proposed by De Verneuil, it is evident that the final grouping was greatly influenced by his suggestions.

In the first volume of the Paleontology of New York, published in 1847, no attempt was made by Hall to form subordinate groups of the several formations included in the lower or "Champlain division," the Potsdam sandstone, Calciferous sandrock, Chazy limestone, Birdseye limestone, Black River limestone, Trenton limestone, Utica shales, Hudson River shales). De Verneuil thought there were several subordinate groups, viz, (1) Potsdam, (2) Calciferous, (3) Chazy, Birdseye, and Black River limestone, (4) Trenton limestone, Utica and Hudson River shales. The placing of the Oneida conglomerate and the Medina sandstone with the Niagara limestone was supported by de Verneuil. It had been proposed by Vanuxem and Mather, but was not followed by Hall; in this review the latter expressed his assent to its propriety.

The combination (Water-lime, Pentamerus galeatus limestone, Delthyris shaly limestone, Upper Pentamerus) to form the Lower Helderberg group, was the suggestion of de Verneuil.[1] This is in accordance with Conrad's identification of this combination with the "Wenlock limestone" in 1841, but does not agree with Hall's previous grouping of the equivalents of the Wenlock limestone.

The inclusion of the Oriskany with the Corniferous in the Devonian was suggested by de Verneuil. The combination Marcellus, Hamilton, Tully, and Genesee as a lower group, and Portage and Chemung as an upper group of the Erie division of the New York reports was also his.

De Verneuil's parallelisms of the strata of Europe and America were as follows:

The Potsdam sandstone he regarded as the equivalent of the "sandstone with obolus" of Russia and the "Carboniferous sandstone" of Scandinavia. The siliceous limestone and Black River and Trenton limestones were the "bituminous schist and Orthoceratite limestone" of Sweden and Russia. The Utica shales and Hudson River group were the "Graptolite slates" of Sweden and of Bain, France. These together form the equivalent of the inferior stage of the Silurian system, and as we study his classification of the next division, it is apparent that the groupings suggested are not those arising from the particular American sequence of rocks, or alone from the faunas themselves, but from their equivalency to the divisions of the European classifications.[2]

In the western exposures in Indiana and Ohio, he recognized a union of the faunas of the Lower and Upper Silurian, but in New York these are separated by the Oneida and Medina arenaceous deposits, and he drew the line so as to include the latter in the Upper Silurian with the Clinton and Niagara. The limestones and shales of the Niagara he regarded as the equivalent of the limestones and slates of Wenlock and

[1] Am. Jour. Sci., 2d ser., vol. 5, p. 180.

[2] Ibid., pp. 179, 180.

of Gothland, and the five inferior groups of the Helderberg division as the equivalent of the Ludlow rocks.

In M. de Verneuil's opinion the Devonian begins with the Oriskany and includes the five superior groups of the Helderberg division and the six groups of the Erie division and the Old Red sandstone. His argument for beginning the Devonian with the Oriskany is the paleontologic equivalency of its fauna with the fauna of the European Devonian, the occurrence of *Asterolepis* in Schoharie grit, and the characters of the numerous *Spirifera*, some of which reminded him of *Spirifer cultrijugatus* and *S. macropterus* of the Eifel, and the fact observed by Hall that the Oriskany was preceded by a violent movement of the waters, denuding and wearing depressions in the underlying rocks. The Oriskany he regarded as the equivalent of the fossiliferous schists of the border of the Rhine. The Chemung, Portage, Genesee, Tully, and Hamilton represented for him the formations of the Eifel and Devonshire; the Marcellus shales, those of Wissenbach in Nassau; the black (Devonian) schists of Ohio, Indiana, and Kentucky, he regarded as representing the Genesee slates of New York, and the calcareous band below represented the Corniferous and Onondaga limestones and the Hamilton group of the East. He held that the Devonian disappears entirely on the borders of the Mississippi, where the Carboniferous system rests directly on the Silurian.[1]

M. de Verneuil first pointed out the fact that the "Waverly series" of Ohio and Indiana in great part belonged to the Carboniferous system, and not to the Devonian or Chemung, as American geologists held.[2] This determination was based upon study of the fossils from near Medina, and from Cuyahoga, and Newark, Ohio. He showed that the representative of the Portage in Ohio was possibly at the base of the Waverly sandstone, but found it difficult to draw a line on account of the lack of fossils, and held the view that in Indiana, Kentucky, and Tennessee all above the black slates is Carboniferous.

In a foot note[3] Mr. Hall explains that he had called rocks at New Albany, Indiana, lying above the black slates and containing Carboniferous fossils, "Subcarboniferous, from the fact that up to that time I was not aware that anything below the base of the great Carboniferous limestone had been recognized as belonging to the Carboniferous period."

In Tennessee the siliceous strata of Prof. Troost are also reported as belonging to the Carboniferous system. Those "Psammites and siliceous strata" M. de Verneuil regarded as equivalent to the "yellow sandstone of Ireland" and the "slates and sandstones of Westphalia."

The reviewer at the close still differed from the author in his definition of the Devonian system above and below, insisting that the limit between Silurian and Devonian should be at the base of the Schoharie

[1] *Am. Jour. Sci.*, 2d ser., vol. 5, p. 181. [2] Ibid., vol. 7, p. 45. [3] Ibid., p. 461.

grit, with the Oriskany left out of consideration, and that the line between the Devonian and Carboniferous was not established and should be regarded as a matter for future determination.[1]

Mr. Hall in this review quotes M. de Verneuil's views as to the great importance of the Paleozoic formations of America:

> No series of formations extended in continuous manner over a vaster surface than the Paleozoic strata of North America. * * *
>
> By one of those happy chances of which the history of science offers us examples, the territory of the State of New York presents us, below the Carboniferous system, the Paleozoic series most complete. Every favorable condition is there also united to facilitate that study, and to give to superpositiop, and consequently to paleontology, of which it is the foundation, a certainty truly scientific.[2]

Hall as well as de Verneuil objected to the unfortunate grouping into "Champlain, Ontario, etc., divisions" of the rocks of New York.

The finer subdivisions are, however, of permanent value. As Hall wrote:

> In truth, we are satisfied that what has given certainty and security to our labors are the minute subdivisions which have never been attempted elsewhere.[3]

The reason for this is not far to seek. These "minute subdivisions" are the natural stratigraphic units of the rocks and express the historical changes of local conditions. They express for each geographic province the epochs of its geologic history and are the units of which the geologic history of the world was built. The fossils they contain are the means by which the history of geographically separate provinces may be compared, and, as will be seen by tracing the effect of de Verneuil's work, the coordinating and systematizing of the several stages of relative uniformity of condition for each separate province are to be accomplished by a comparative study of the fossil contents.

The reason for grouping any particular formation with those below rather than with those above is not found in its mineral constitution, nor in its stratigraphic condition, but in the character of its fossil contents.

The New York geologists attempted to make groupings of the fundamental formations based upon their relation to the present geographic features of the surface. This plan failed because there is no natural connection between the two sets of phenomena.

When de Verneuil discussed the matter with Hall on a basis of the fossil contents of each particular formation for each particular geographic province, a natural classification was reached, which, as far as the state of knowledge permitted, was satisfactory, and which persists because it is based upon facts which have a history, and therefore can be historically classified.[4]

In Tennessee, according to the reports of Troost and Owen, Silurian,

[1] Am. Jour. Sci., 2d ser., vol. 7, p. 231.

[2] Ibid., vol. 5, p. 177.

[3] Ibid., p. 179.

[4] Comparison of the geological features of Tennessee with those of the State of New York, by James Hall; Proc. *Amer. Assoc., 1851, vol. 6, pp. 256-259.*

Devonian, and Carboniferous species occur together. Hall accounted for this fact by the absence in this basin of the rocks which in New York separate these great limestones, thus bringing the representatives of the Niagara, Lower Helderberg, and Corniferous together, and causing some confusion of the species at their junction.

This was in the direction of clear definition for the faunas. Up to this time (and to some extent even to the present), geologists did not appreciate the essential importance of knowing the precise order and association of species making up the successive faunas met with in geological sections.

James Hall also prepared a paper on "Parallelism of the Paleozoic deposits of the United States and Europe."[1] This was written after the work on the geological survey of the State of New York had been completed. Interest had also been excited in Europe, and he had the benefit of the studies of several very able European geologists. Lyell had visited America the first time; de Verneuil had written his paper on the Parallelism of the Paleozoic formations of America with those of Europe; Daniel Sharpe had written a paper on the Paleozoic rocks of North America;[2] Murchison's Silurian System had been published several years before; also Phillips's Fossils of Devonshire, and McCoy's description of Carboniferous Fossils; these were all published and at hand for comparison.

The first part of Mr. Hall's paper was devoted to a comparison between the Paleozoic rocks of New York and those of the West. As bearing upon our present discussion the only point of particular interest in this comparison is the correlation of the "Cliff limestone" with the Niagara, Clinton, and Corniferous limestones of the East. In the West a black shale was found to follow this limestone in some parts of Ohio, Indiana, and Kentucky, which was believed to represent the remaining part of the Devonian; above it, all over the Mississippi Valley area, the Carboniferous limestone appeared. Several interesting points appear in the discussion of the comparisons between the American and the European sections made by Messrs. Sharpe, de Verneuil, and others. In these comparisons the use of fossils was paramount, and all the arguments were based upon the presence of fossils, irrespective of the lithologic characters of the deposits. The determinations were based chiefly upon a numerical comparison of the recorded lists of fossils; resemblance of genera and identity of species were recorded as determining the correlation in each case. This principle was carried to the extent of recognizing, in species from what are called now Devonian deposits of America, correlations with Silurian, Devonian, and Carboniferous species in the different groups of organisms which were compared. For instance, in a table[3] the Brachiopods of the Oriskany sand-

[1] It appeared as chapter XVIII of Foster and Whitney's Report on Lake Superior, part II, pp. 285-318, published in 1851.

[2] *Quar. Jour. Geol. Soc. Lond.*, August, 1848.

[3] *Ibid*, p. 316.

stone are said to indicate a "close affinity with the Carboniferous;" the Cephalopoda of the Marcellus and the Brachiopoda and some Cephalopoda of the Chemung and Hamilton groups are reported as "of Carboniferous facies." Again, the Brachiopods and Lamellibranchs of the Chemung and Hamilton, and the Brachiopods of the Corniferous are indicated as presenting a "Devonian facies," while the Lamellibranchiata and Orthocerata of the Chemung and Hamilton, the Cephalopoda of the Corniferous, and the Cephalopoda and Crustacea of the Schoharie grit are regarded as "equivalents of the corresponding faunas of the Ludlow rocks in Europe."

This indicates considerable confusion, and the inference to be drawn from a study of these results is that the determination of the fossils was not sufficiently accurate to make the comparisons with precision. It is probable that the difference between the species which were defined as "Carboniferous," or "Devonian," or "Upper Silurian (Ludlow)" in Europe, belonging to the same genera, was not so great as the difference which the species, belonging to the same horizon, might exhibit on the two sides of the ocean; but at this stage in the progress of paleontology there was apparen tly very little appreciation of the amount of variation which species of the same genus undergo during the same geologic epoch.

Hall was of the opinion that the Upper Helderberg of the New York system represented the Ludlow group of Murchison, and while he recognized the fact that the Ludlow beds were separated by the English from the Devonian, he insisted that the fossils of the Ludlow were represented by the fossils of the Schoharie grit and Corniferous limestone more closely than by any of our Lower Helderberg species. He insisted that either the Ludlow beds belonged to the Devonian or that there must be some consider able gap in the New York series between the Lower Helderberg and the Upper Helderberg. He said, after stating that he could not agree with M. de Verneuil in placing the Lower Helderberg limestones in parallelism with the Ludlow:

> Leaving out of consideration the Oriskany sandstone and Cauda-Galli grit, we feel disposed to regard the Schoharie grit as possessing zoological features more in accordance with those of the Lower Ludlo w series than any other rock in our classification. We shall thus place it for the present.[1]

And in his table of equivalents the Wenlock series is represented by the Clinton group in part, Niagara group, and Lower Helderberg limestones; and the Ludlow series and Devonian system are represented by our Upper Helderberg limestones, Hamilton group, Chemung group, and the Red sandstone and shale of the Catskill Mountains.[2]

As indicative of the stage of refinement reached in the identification of species and its results, the following quotations may be made:

> Although it is not difficult to find the evidence of a general parallelism in our suc-

[1] Foster and Whitney, Rept. on Lake Superior, pt. 2, p. 310. [2] Ibid., p. 317.

cessive groups with those of Europe, yet when we come to more minute and critical comparisons the difficulties increase rather than diminish.

The relations of our divisions often appear to be in two directions, and it is impossible to account satisfactorily for the apparent divergence in the direction of groups, as shown by the evidence afforded by the recognized species of European authorities.[1]

This determination of (correlation with) the Ludlow was independent of his determination of the true representative of the Devonian system in America; for in another place he said:

The Oriskany sandstone, however, marks an important horizon, since we now regard it as commencing the Devonian period.[2]

Although fossils were used for the purpose of correlating formations across geographic intervals, as from England to America, it was not by paleontology pure and simple. It was an identification of strata by likeness of fossils irrespective of the question of paleontologic history. The fossils were mere "medals of creation;" those possessing the same marks were supposed to belong to the same creation. The time had not come for an examination of the relations of the various fossils to each other. The law of paleontologic succession did not become a factor of correlation till the idea of the evolution of species furnished a rational basis of confidence in the naturalness of the observed order of sequence of forms. The idea of evolution suggests the true biologic system of correlation, in which the data of the classification are fossils, and the distinctions made are into periods in the history of organisms, the strata taking their relative position in the series according to the period in this history which their contained fossil remains may indicate.

[1] Foster and Whitney, Rept. on Lake Superior, pt. 2, p. 314. [2] Ibid., p. 302.

CHAPTER III.

THE DIFFERENTIATION OF THE CARBONIFEROUS SYSTEM.

In matters of correlation the Carboniferous system is particularly unfortunate, in that there is nothing in the name nor in the usage to determine precisely the limits of the system above and below. The grand divisions Lower Carboniferous, Millstone Grit, and Coal Measures have been handed down from the early classifications before strict methods were in use. The question whether the Permian shall constitute the third age of the Carboniferous period or not must be settled either arbitrarily or by reference to precedent. In order to establish a precedent it must be determined what is the standard Carboniferous system. If the original Carboniferous system excluded the Permian as a distinct system it is important that a name be found to designate that usage and to distinguish it from the present common usage, which includes the Lower Carboniferous, the Coal Measures, and the Permian in the one Carboniferous system. A review of the literature shows that a classification of the rocks to form a system to which first the name Carboniferous was applied was made by W. D. Conybeare in 1821.[1] It was called the "Medial or Carboniferous order," and was defined to include: (1) The Coal Measures, the "independent coal formation" of Werner; (2) the Millstone grit and shales; (3) the Carboniferous or Mountain limestone; and (4) the Old Red sandstone.[2] This grouping of the rocks was suggested by their "association together in the districts which afford the principal deposit of fossil coal."[3]

In this classification the "New Red sandstone," including what is now called "Permian" and "Trias," was distinctly excluded, and we discover that the New Red sandstone beds in England generally rest unconformably upon the Carboniferous. The line of unconformity gave occasion for the distinction between "primary" and "secondary," and later "transition" and "secondary," and for the classification of the rocks and faunas below the line as "Paleozoic" and those above as "Mesozoic." In the Wernerian nomenclature the term "Floetz class" was applied to the flat-lying rocks, beginning with those New Red sandstones in the English series and running upward.

Conybeare's Carboniferous order also included rocks correlated as Old Red sandstone, and he recognized that the "Old Red approaches in its lowest beds very nearly to the characters of the graywacke upon which

[1] Conybeare and Phillips: Outlines of the Geology of England and Wales, London, 1822, p. 333.
[2] Op. cit., p. 335.
[3] Op. cit., p. 333.

it reposes, and indeed graduates insensibly into that rock, so that the line of separation between them is frequently only an imaginary and arbitrary demarkation."[1]

Thus we see that the Carboniferous as originally understood was grouped about the Coal Measures, had its upper limit a line of unconformity, and below had no sharp line of demarkation.

Murchison and Sedgwick had previously recognized the importance of the Old Red Sandstone as a distinct terrane, and as holding a peculiar and interesting fauna,[2] and in 1839, in the Silurian system, Murchison raised it to equal rank with the Silurian and Carboniferous, calling it the "Old Red system."

Murchison included in the Carboniferous system the rocks associated with the Coal Measures, which are terminated above by the rocks of the New Red system, and below by those of the Old Red system. The three divisions of the Carboniferous system (Coal Measures, Millstone grit, and Carboniferous limestone) were recognized by Murchison.

The Old Red system of Murchison included: (1) Quartoze Conglomerate and sandstone; (2) Cornstone and marl; (3) Tilestone.

Immediately under the Tilestone at Ludlow village was the Upper Ludlow and top of his Silurian system. The Tilestones were regarded as beds of passage to the Silurian. They were afterward called "Downton sandstone," a name proposed by John Phillips.

This was the classification with which the New York geologists sought to correlate the rocks of the New York system in 1840.

The Carboniferous system was made up of the Coal Measures at the top, the Millstone grit, and at bottom the Carboniferous limestone. Above the Carboniferous came the New Red sandstone or New Red system, in which the Magnesian limestone, the Saliferous group, and the New Red sandstone were conspicuous divisions. Below the Carboniferous came the Old Red system, which in Murchison's classification filled the interval between the Carboniferous and Silurian systems.

The confusion about the Devonian in the final reports of the New York survey arose partly from the original confusion in England. The series in New York are perfectly simple up to the Conglomerate. The Red rocks of the Catskill were identified with the Old Red system. The Devonian rocks were clearly below these Catskill rocks, and while some of their fossils were similar to Phillips's Devonian fossils, others were also like Murchison's Ludlow fossils, and as the Ludlow group immediately preceded the typical Old Red rocks of England, and as the chief of Phillips's Devonian fossils were really Upper Devonian, it was natural to conclude that the rocks of our Middle and Lower Devonian were to be correlated with the Ludlow rocks of Murchison.

The correcting of this mistake could come only from a careful study of the fossils. When this had been done by de Verneuil the correc-

[1] Op. cit., p. 862. [2] Geol. Trans., vol. 3.

tion was made; but Hall accepted it only after making a careful study of the fossils for himself. To Hall the New York rocks were the standard. To de Verneuil, Sharp, and Lyell the English rocks were the standard, and they had no prejudices in favor of any particular interpretation of the American rocks. The lithologic characters were prominent in Hall's correlation; to the English geologists, and particularly to de Verneuil, fossils were the chief criteria.

In the Carboniferous system the lack of a representative of the Carboniferous limestone in the Pennsylvania sections led to confusion, in early reports we read of the Coal Measures as "secondary," and of "transition coal-beds." (1835.) It was, doubtless, this supposition that the true order was (1) limestone, (2) grit, (3) Coal Measures, that led the Ohio geologists[1] to correlate the Corniferous limestone underlying the shales and fine-grained sandstone (Waverly) with the Mountain limestone.

The Wernerian idea that anthracite coal belonged to the "greywacke" or "transition," as taught in Conybeare and Phillips's geology in 1822, and imitated elsewhere,[2] was the influencing cause of the erroneous views as to the position of the eastern coal-beds of Pennsylvania, as seen in the papers of James Pierce and William Meade,[3] and others following up the discussion. In Tennessee the Mountain limestone was rightly classified, because there the limestone was actually next below the Coal Measures.

A remarkable example of error arising from this firm belief in the identity in the order of lithological deposits for America and England is seen in the paper of Prof. C. Dewey,[4] who in 1838 interpreted the red rocks about Rochester (Medina) as Old Red, and the overlying limestones (Niagara) as ranking wtih the Mountain limestone of Europe.

In the Mississippian province the identification of the rocks from the Coal Measures downward was correctly made, not because of accurate knowledge of the fossils, but because the three grand divisions of the typical English Carboniferous system were there present in the same order: first, a series of limestones, then conglomerate or sandstone, then Coal Measures.

Thus it came about that the true classification of the Carboniferous was through the western or Mississippi Valley formations, and not through the typical Appalachian sections in Pennsylvania and southward, and their subdivision was made independently of the European usage. The base was determined by the fossils of species allied to the species of the Carboniferous limestone of England.

In the Appalachian province the limit was determined by the top of the marine Devonian rocks. But in the case of the upper limit, while the general custom in America has been to regard the Coal Measures as

[1] Ohio Geol. Survey, 2d Ann. Rep., by W.W. Mather, 1838.
[2] Geological Nomenclature, by Amos Eaton, 1838.
[3] See Am. Jour. Sci., 1st ser., 1827, vol. 12, pp. 69, 76.
[4] *Am. Jour. Sci., vol. 33, p. 121.*

the top of the Carboniferous system and to treat the appearance of the Permian type of fossils as indicating a new system, there has been no recognized standard for the settlement of the question.

In the same way at the base, where the last Devonian fossils are separated from the Coal Measures by deposits lacking marine fossils, the determination of the line of division between Devonian and Carboniferous has occasioned considerable dispute, which would certainly have been less had there been a recognized standard section of the Carboniferous system outside America which might be referred to as a standard in all cases of difference of opinion about our own rocks.

In order that we may have such a standard, I shall describe more in detail the Carboniferous system as first defined for English geologists.[1]

The English author who first appreciated the importance of grouping certain rock formations with the Coal Measures to form what now is called a system, was W. D. Conybeare.[2] The German geologist, Werner, and the school of geologists that followed him, had called the Coal Measures the "Independent Coal Formation" or "Stein Kohlengebirge." Conybeare subdivided the "Transition and Secondary formations" of Werner into orders, and his medial order was called the "Medial or Carboniferous order." Here were included "the rock formations, which ought to be considered together with the Coal Measures." In his classification these formations were, "I. The Coal Measures. II. The Millstone grit and shale. III. The Carboniferous or Mountain limestone. IV. The Old Red sandstone."[3] His "Supermedial order" included all the rocks from the Coal Measures to the Tertiary, substantially what we now call Mesozoic. His Submedial order was the "Grauwacke" of Werner.

Conybeare prominently notices that the formations of the "Medial or Carboniferous order" are the rocks which form the "Pennine chain" (spelled by him *Penine*) of mountains in northern England. He carefully defines the position and structure of the range, and proposes the retention of the name "Pennine," which was first applied to them by the early Roman colonists of the island.[4] Other exhibitions of Carboniferous rocks are mentioned by him, but here alone he found the whole series represented, and the rocks of the Pennine range were the typical rocks of the system which Conybeare defined.

In Hughes's "Geography of British History" (London, 1863), we find the "Pennine range" defined as "applied by general consent to the extensive range of high ground stretching south from the Cheviot Hills to the district of the Peak in Derbyshire, about 170 miles in length," stretching from the border of Scotland southward to the val-

[1] A portion of this chapter has been read before the Indianapolis meeting of the American Geological Society, and an abstract appears in its bulletin, vol. II, pp. 16–19.

[2] Conybeare and Phillips, Outlines of the Geology of England and Wales. London, 1822, p. 323.

[3] Op. cit., p. 325.

[4] *See* Outlines of the Geology of England and Wales, pp. 365, 366.

ley of the Trent."[1] It is composed "entirely of rocks belonging to the Carboniferous series."[2]

H. B. Woodward, in "Geology of England and Wales" (1887), describes this range as "a faulted anticlinal of Lower Carboniferous rocks supporting on the east the coal fields of Northumberland, Yorkshire, and Derbyshire, and on the west the Lancashire and Cheshire coal fields."[3]

As was pointed out by Conybeare, the rocks of this range not only contain the typical rock formations to which he applied the name "Carboniferous order," but each of the members of that system.

De la Beche (1831–1833) followed the classification of Conybeare, but dropped the term "Medial" as a synonym. John Phillips (1837) adopted the name "Carboniferous" with "system" instead of "order" in the same sense as proposed by Conybeare. And Murchison, in the Silurian system (1839), made classic the names "Silurian system," "Old Red system," "Carboniferous system," "New Red system," and "Oolitic system."

After them, geologists in general adopted the name Carboniferous system for one of the great groups of rocks composing the grand geological column.

All of these early English authors were in unison in distinctly excluding the rocks afterward (in 1841) called "Permian" by Murchison, and at that time going under the names "New Red sandstone" and "Magnesian limestone," "Saliferous system" and "New Red system." Conybeare, De la Beche, and John Phillips agreed in including the "Upper Old Red sandstone" in the Carboniferous system, while Murchison, after them (in 1839), separated from the Carboniferous the lower member as a distinct system. On page 169 of his Silurian system he says that he "applied the name 'Old Red system' to the Old Red sandstone of previous writers in order to convey a just conception of their importance in the natural succession of rocks, and also to show that as the Carboniferous system in which previous writers have merged it * * * is surmounted by one red group, so is it underlaid by another."

Thus, all four of these early authorities in English geology agree in their definition of the original Carboniferous system, which is that of *the series of rocks typically represented in the Pennine range of England, and not fully represented in any other one section of England.*

When we seek to determine the precise definition of the Carboniferous system, we are led directly to this typical section in the Pennine range, first clearly defined by Conybeare, and afterward adopted as the typical section by the founders of geological science in England, and afterward by correlation recognized as the standard section of the Carboniferous system throughout the world. The section of this typical Pennine Car-

[1] Op. cit., p. 20. [2] Op. cit., p. 22. [3] Op. cit., p. 149.

boniferous system consists of, first, the upper part of the Old Red sandstone resting upon lower beds of Old Red sandstone, unconformably about the Cheviot Hills, or upon the Cheviot Volcanic series, or upon Silurian rocks, as in Northumberland. The second formation, resting conformably upon the first, is the Mountain or Carboniferous limestone. The third member of the series is the Millstone grit and shales. The fourth, the Coal Measures, including the familiar coal fields of Lancashire and Cheshire, of Yorkshire, Northumberland, and Derbyshire; these latter are terminated where contacts are seen by the "New Red," in some places apparently conformably, but generally unconformably. The system in this Pennine range was evidently terminated both below and above by geologic disturbance of greater or less extent, furnishing natural deliminations, thus peculiarly fitting it for a standard of geologic definition.

An analysis of the standard systems in geologic classification shows us that a system is a series of rock formations whose stratigraphic order and lithologic composition are thoroughly well expressed in some definable geograpic region, and whose fossils indicate a continuous biologic sequence, more or less distinctly broken at its lower and upper limits from contiguous formations. Thus a typical section has definite geographic position, geologic delimitation, and biologic definition. The Silurian system in Wales and western England, the Devonian system of south and north Devonshire, the Jurassic system of the Jura Mountains, are examples, and no less perfect is the Pennine Carboniferous system of the Pennine range of north England to which the unsatisfactory name of Carboniferous has been so long applied.

While so much is true of the standard or typical expression of a geologic system, it can not be expected that any system will offer precisely the same features in other regions of the world or on other continents. We conclude, therefore, that: (1) Because the composition, the size of particles, and the order and thickness of deposits are all determined by conditions that are geographically dissimilar, therefore a geologic system can have but one typical geographic position; (2) because the geologic events, such as elevation of land, breaking of strata recorded in faults, and volcanic eruptions, do not take place either uniformly or simultaneously in different parts of the earth, it is certain that intervals or breaks in sedimentary formations will not be uniform for separate regions; and (3) because organisms in the past can not be regarded as having ceased to carry on the ordinary functions of life and reproduction, all the breaks in the sequence of organisms, all the sharp lines distinguishing the faunas or floras of one formation from those of a preceding or following formation, are local and not universal.

To apply these reflections to the present case, it will be seen that the settlement of the question as to which is the typical section upon which the Carboniferous system was founded, will greatly facilitate all attempts to determine the limits of the system in other regions. It is evident

that the typical section is the section exhibited in the Pennine range, and as the name Carboniferous is a misnomer geologically (for we now know that carbon or coal-bearing rocks are not confined to the system generally so called), and as the name does not indicate the geographic position of the typical section, it is believed that the adoption of the name "Pennine system" may be of advantage to the science, for this particular type of the Carboniferous system.

This Pennine Carboniferous system may be defined as to its *geographic position*, as the rock formations of the Pennine range of northern England and equivalent formations in other parts of the world. In *geologic delimitation* the Pennine system begins with a red sandstone and terminates with the upper rocks of the Coal Measures. In *biologic definition* its first marine fauna is that of the Mountain limestone; its final fauna and flora are those of the Coal Measures. The brackish fauna of the Old Red sandstone had not ceased at its opening; the characteristic Permian fauna or flora had not appeared at its close.

Whatever may prove to be the correlation between the Old Red sandstone and the Devonian systems, the definition of the Pennine system is explicit in including fishes, such as *Holoptychius*, characteristic of the Old Red system of Murchison, and is as explicit in the exclusion of the Devonian marine fauna above which its earliest marine fauna belongs. The rocks and faunas of that which was later called the Permian system, are definitely excluded by the original author from the Pennine Carboniferous system. The problems of the Devonian Old Red system and of the Permian system must be discussed on their own merits. This original section of the Carboniferous has its relations to each clearly defined.

In correlating our American rocks the recognition of the Pennine Carboniferous system as typical, settles for us several disputed questions. For the Paleozoic rocks along the Appalachian and eastern border region the limits between Devonian and Pennine Carboniferous are in the following positions: The Chemung marine fauna is strictly Devonian; the brackish water fish fauna of the Catskill is as strictly Pennine. Hence the red rocks of the Catskill formation of New York, the Ponent, Umbral, and Vespertine formations of Pennsylvania, belong to the Pennine Carboniferous.

When, as in western Pennsylvania and Ohio, the species of the Carboniferous or Mountain limestone fauna of England appear to follow the marine Chemung, the line should be drawn between them for a strict correlation.

On passing westward the formations called Waverly, Marshall, Kinderhook, Chouteau, containing as they do a fauna distinctly related to the Carboniferous limestone fauna, must be placed in the Pennine Carboniferous system.

In Kansas and Nebraska, and other localities where the upper Coal Measures gradually assume species of the types described from the

Russian Permian, the problem of correlation is definite. Both the stratigraphy and the biological evidence indicate that there is no sharp division between the representative of the Pennine Carboniferous system and that of the Permian system. The division line here must be arbitrarily drawn, and the fact that a system is a local series of formations, and not a universal subdivision of the geologic time scale, becomes evident. It is in such cases that the paramount importance of the determination of the geographic position of the typical representative of a system is seen, and the only way to make this apparent to all is by all the association of the geographic name with the system.

CHAPTER IV.

THE COAL MEASURES OR PENNSYLVANIA SERIES. THE DEVELOPMENT OF ITS NOMENCLATURE AND CLASSIFICATION IN THE APPALACHIAN PROVINCE.

The classification of the rocks of middle Pennsylvania in 1836 furnished the basis for the system of numbers which have played so conspicuous a part in Pennsylvania geology ever since. The State geologist was Henry D. Rogers, and his assistants were D. C. Booth and J. F. Frazer, with R. E. Rogers as chemist. The classification was as follows:

XII.	Coal Measures.	
XI.	Red shale.	
X.	White sandstone,	of the second mountain.
IX.	Red sandstone,	
VIII.	Olive shales, etc.	
VII.	Cherry sandstone.	
VI.	Limestone.	
V.	Red shale and Fossil ore.	
IV.	Gray sandstone,	of the first mountain.
III.	White sandstone,	
II.	Slate,	of the Lebanon Valley.
I.	Limestone,	

The State geologist believed that this series of formations in the order given could be recognized "under slight variations of color, size, and mineral ingredients, across the Old Dominion and into Tennessee and Alabama."[1]

This constituted the "series of Appalachian formations," which Prof. Rogers "for the first time systematically classified and described in the years 1836, 1837, and 1838."[2]

The geological survey of Pennsylvania was begun in 1836 and several annual reports were published, but the final report was not published till 1858.[3]

[1] Second Geol. Survey of Pennsylvania, 1874–'75–'76. Historical sketch of geological explorations in Pennsylvania and other States. By J. P. Lesley, 1876, pp. 54, 55.

[2] Second Annual Report on the Geological Exploration of the State of Pennsylvania. By Henry D. Rogers, State Geologist. Harrisburg, 1838, pp. 82, 83.

[3] The Geology of Pennsylvania, a Government survey, with a general view of the geology of the United States; essays on the coal formation and its fossils and a description of the coal fields of North America and Great Britain. By Henry Darwin Rogers, State Geologist. 4to, 2 vols., Edinburgh, London, and Philadelphia, 1858.

Prof. Rogers's system of classification and nomenclature is exhibited in the following synopsis:[1]

A SYNOPSIS OF THE APPALACHIAN PALEOZOIC STRATA OF PENNSYLVANIA IN THE ASCENDING ORDER.

Primal crystalline schists (or Azoic group).

	Feet.
Primal series:	
Primal Conglomerate in Virginia and Tennessee	150
Primal older slate in Virginia	1,200
Primal White sandstone, Potsdam sandstone of New York	?300
Primal upper slate	?700
Auroral series (blue limestone of the Western States):	
Auroral Calcareous sandstone, Calciferous sandstone of New York	60
Auroral Magnesian limestone, the Chazy and Black River limestones in part	2,500–5,500
Matinal series:	
Matinal argillaceous limestone, Trenton limestone of New York	300–550
Matinal Black slate, Utica slate of New York	300–400
Matinal shales, Hudson River slate	?1,200
Levant series:	
Levant gray sandstone, Oneida Conglomerate of New York	250–400
Levant Red sandstone, division I, or lowest member of Medina sandstone of New York	500–700
Levant White sandstone, apparently divisions II, III, IV, Medina sandstone of New York	450
Surgent series:	
Surgent lower slate, ? equivalent of lower green shale of Clinton group of New York	200
Surgent iron sandstone	80
Surgent upper slate	250
Surgent lower ore shales, ? in horizon of upper green shales, Clinton group	760
Surgent ore sandstone	10–30
Surgent upper ore shales, ? in horizon of upper green shales, etc	300
Surgent red marl, Clinton group	350
Scalent series:	
Scalent variegated marls Scalent gray marls ? Onondaga salt group of New York	400 800
Scalent limestone, Water-lime group of New York	250
Pre-Meridian series:	
Pre-Meridian limestone, Lower Helderberg limestone of New York	50–100
Meridian series:	
Meridian slate	170
Meridian sandstone, Oriskany sandstone of New York	150
Post-Meridian series:	
Post-Meridian grits, Cauda-Galli and Scoharie grits of New York (New Jersey)	300
Post-Meridian limestone, Upper Helderberg or Corniferous limestone of New York, and part of Cliff limestone of Western States	80
Cadent series:	
Cadent lower black slate, Marcellus shale of New York	250
Cadent shales, Hamilton group of New York	600
Cadent upper black slate, Genesee shale of New York	300

[1] Op. cit., vol. I., pp. 105–109.

	Feet.
Vergent series:	
Vergent Flags, Portage flags of New York	1,700
Vergent shales, Chemung group of New York	3,200
Ponent series:	
Ponent Red sandstone, Catskill group of New York	5,000
Vespertine series:	
Vespertine Conglomerate and sandstone	2,660
Umbral series, or Carboniferous shales and limestone:	
Umbral Red shales and limestone	3,000
Seral series, or Coal strata:	
Seral Conglomerate, or lowest division of Coal Measures	1,100
Lower Productive Coal Measures.	
Lower Barren Coal Shales.	
Upper Productive Coal Measures.	
Upper Barren Coal Shales.	

The numbers corresponding to the names here proposed are as follows:

XII. Seral.	VI. Pre-Meridian.
XI. Umbral.	V. { Scalent. Surgent.
X. Vespertine.	IV. Levant.
IX. Ponent.	III. Matinal.
VIII. { Vergent. Cadent.	II. Auroral.
VII. Meridian.	I. Primal.

In 1850 H. D. Rogers[1] discussed the coal formations of the United States, considered from the following points of view:

First. The source, stratigraphical relations, and conditions of deposition. The land-derived deposits, attaining a maximum thickness of 1,400 feet in the southeast, thin out westward to less than 100 feet, and the Coal Measures gradually thicken toward the northwest. The immense range and horizontal extension of the conglomerates and coal seams prove that it could not have been deposited by any local *estuary* or *deltal* actions, but along a broad, shallow sea shore, which was disturbed by violent interior forces, producing enormous undulations.

Second. The author discussed the structural conditions and position of the anthracite basins, and found them arranged in two systems of flexures, the larger series with an amplitude of many miles and a length of 100 miles, with average direction of about N. 75° E., the smaller series trending N. 70° E.

Third. He treated of the metamorphism of the anthracite coal-bearing strata, showing it to be more complete in the east, the products of the western region being bituminous and those of the east anthracitic.

Fourth. Erosion is considered.

Finally, a summary of the statistics of the coal fields is presented, in which the author states that the productive area of the anthracite fields of Pennsylvania does not exceed 200 square miles, with an aggregate thickness of 100 feet.

[1] On the coal formation of the United States, and especially as developed in Pennsylvania. Proc. Am. Assoc., vol. 4, 1850, pp. 65–70.

The same author[1] determined the age of certain footprints from the red shale near Mount Carbon.

Ancient footprints discovered by Mr. Isaac Lea in the "Red Shale" at Mount Carbon, in Pennsylvania, and assigned by him to the Devonian period, were considered by the author to belong in reality to the "Reds" of the Carboniferous, a few hundred feet below the productive coal series. They are accompanied by a series of similar footprints attributed to batrachian reptiles, trails, prints of some unknown four-toed animal apparently reptilian, and trails analogous to those of worms and mollusca. The larger footprints are mainly five-toed, alternate in the steps, and nearly equal in size.

In 1856 Mr. J. P. Lesley reported on the Broad Top coal basin.[2]

The Broad Top coal basin, situated between Huntingdon and Bedford Springs, was imperfectly reported upon in 1838 by Mr. McKinley, the substance of the report appearing in the annual reports of the Geological Survey.

In 1855 the author made a more complete survey of this region, covering about 80 square miles, established the levels of over nine thousand points, and reached the following conclusions: (1) That the succession of the measures is not different from the system made out in western Pennsylvania and eastern Ohio. (2) That the structural results lead to the conclusion that the abruptness of the anticlinals could be produced only by side pressure. (3) That the Precarboniferous Coal Measures are represented in this region by beds of black slate containing little coal, the Subcarboniferous limestone being present in small amounts.

J. P. Lesley,[3] remarking on the Subconglomeratic Coal Measures of northwestern Virginia, thinks those beds represent early Carboniferous formations, such as are seen in Ireland, Scotland, and possibly in Melville Island. Similar beds occur in southern Virginia, in southeastern Kentucky, and in Nova Scotia. The lowest Devono-Carboniferous slate represents a still earlier period, and may be correlated with the German Devonian Coal Measures.

Mr. J. M. Hale[4] (1864) reported at the junction of the Beaver Dam and eastern branches of Clearfield Creek, a boring of 548 feet. At the depth of 199 feet a vein of coal 4 feet 4 inches in thickness was reached. This is probably in the author's view the same vein as at Osceola or Phillipsburg.

Mr. B. S. Lyman,[5] in 1867, commenting on the Great Carboniferous

[1] Rogers, H. D.: On the position and character of the reptilian footprints in the Carboniferous Red Shale formation of eastern Pennsylvania. Proc. Am. Assoc., vol. 4, 1850, pp. 250-251.

[2] Lesley, J. P.: On the Broad Top coal basin in central Pennsylvania. Am. Assoc., vol. 10, pt. 2, 1856, pp. 78-81, map.

[3] Lesley, J. P.: On the Subconglomeratic or false Coal Measures of West Virginia and Pennsylvania. Am. Phil. Soc., Proc., vol. 7, 1860, p. 294.

[4] Hale, John M.: Record of an old salt boring in Clearfield County, Pennsylvania. Am. Phil. Soc., *Proc., vol. 9, 1865, pp. 459-460.*

[5] *Abstract on the Great Carboniferous conglomerate in Sullivan County, Pennsylvania.* Phil. Acad. *Sci., Proc., vol. 19, 1867, pp. 125-127.*

conglomerate, stated that it was the general opinion that the Great Conglomerate (No. XII) at the bottom of the Coal Measures thins out rapidly from a thickness of 1,200 feet at Manch Chunk to less than 100 feet in Wyoming Valley. But he found in Sullivan County a thickness of 400 feet, consisting of two main layers of pebbly rock separated by strata of light brown and greenish sandstones resembling those of the productive Coal Measures. The lower bed is well exposed at Shinerville, where it dips 15° S., and again on the south side of Loyal Sock. Farther south are the red, iron-stained shales (No. XI) north of Painter Den Run, and still farther south the sandstone (lower bed) outcropssouth of Bear Swamp Run. The sand rock also occurs at Long Point, where it has a thickness of 190 feet. Close examination of the sand rocks at this point led to the conclusion that they are the same as at Shinerville and Birch Creek, 1 mile distant.

Mr. J. S. Newberry,[1] in 1871, gave an account of some sections of the lower Coal Measures in Holmes, Tuscarawas, Jefferson, and Columbiana Counties, which in some cases extend down to the Waverly, and show alternations of shale, sandstones, and limestones, with beds of coal. The sections average from 300 to 400 feet in depth, the coal seams individually rarely more than 4 feet. The coal beds are numbered according to altitude, from 1 to 7, No. 1 being the lowest, and are described in detail. Coal, No. 6, in Holmes County, is overlaid by a black bituminous shale, rich in marine fossils, *Chonetes mesolaba*, etc. At the mouth of the Yellow Creek, Jefferson County, the "Big Vein" of coal is underlaid by 4 inches of cannel, full of the remains of fishes and amphibians; the fishes, species of *Calacanthus* and *Eurylepis*, *Palæoniscus* and *Rhizodus;* the amphibians were aquatic carnivorous salamanders.

William M. Fontaine,[2] in 1874, stated that the Great Conglomerate on New River consists of a great formation of sandstones containing important beds of coal, underneath a massive white sandstone, which itself underlies the lowest strata of the Lower Coal series. This formation is considered by William Rogers the equivalent of the Great Conglomerate, here much expanded, while others hold that it is a great development of the Lower Coals. To the east it is underlaid by the enormously expanded Subcarboniferous group.

Fontaine gave facts concerning the overlying and underlying formations of this peculiar series, beginning at the mouth of the Kanawha River where the strata are of Upper Coal series, diminished in thickness. Under these is found the barren upper portion of the Lower Coal series, increased rather than diminished in thickness, developing both to the south and to the northeast. The strata under these barren

[1] Newberry, J. S.: Sketch of the structure of the lower Coal Measures in northeastern Ohio. Geol. Survey Ohio, Report Progress in 1870, pt. 1, pp. 14–53. Columbus, 1871.

[2] Fontaine, Wm. M.: The "Great Conglomerate" on New River, West Virginia. Am. Jour. Sci., 3d ser., vol. 7, pp. 459–465, 573–579.

measures are of great thickness, and the author gives a section showing the number and thickness of the coal seams in this Lower Coal series. After this series comes the Conglomerate series, introduced by a massive white sandstone, remarkable for its resistance to erosion. The strata underneath it, best exposed at Sewell Station, resemble strongly the rocks of the Lower Coal series, are argillaceous, and contain considerable amount of oxide of iron, but they differ from the latter by the almost entire absence of shales in connection with the coal beds. The coal seams are inclosed in flaggy sandstones; all the evidence goes to show that they were formed under sudden and violent changes. Measurements are given of the different seams showing a great variation in thickness. Some Devonian plants have been found in the roof of the deposits, of which *Alethopteris serlii* is the most abundant. Underneath these conglomerate sandstones and coal seams is another massive white sandstone, evidently the base of the formation. The next lower deposits are heavy bedded sandstones succeeded by the red shales of the Subcarboniferous formation.

This lowest coal series on New River has the same triple structure shown by the Conglomerate in other portions of the country, a summit and base of conglomeritic sandstones, and a central portion of more argillaceous rocks containing beds of coal, and the thickening of the whole formation is mostly due to the expansion of the middle portion followed by an increase in the amount of coal. Brief descriptions of the Conglomerate at other points are given to confirm these statements. The Conglomerate is seen to expand in two directions, to the northeast into Pennsylvania, and to the southwest in West Virginia, while it diminishes to the northwest. The expansion to the southwest is followed in each case by the increased formation of coal. The similar expansion of the underlying rocks, the Subcarboniferous and the Catskill, is treated in detail. A thin seam of coal is found in the latter containing many beautifully preserved Devonian plants, confirming the supposed Catskill age of the strata. Several species of *Lepidodendron*, *Cyclopteris*, *Neuropteris*, and others are found.

The great expansion of the Conglomerate on New River is thus found to be like others, the effect of a condition of things which began in much older formations and continued until a later era. The author asks the question, "Does not the successive formation of coal on an extended scale, along the southwest border of the Appalachian coal field, commencing in the Devonian period, point to the existence at this time of a continental mass nearer than the Azoic of Canada?"

J. J. Stevenson,[1] in 1874, made the following report on the coals of the Kanawha Valley:

The Upper Coal group along the Great Kanawha River has two coal beds of workable thickness. The lower one is the Pittsburg, usually known as the "Raymond

[1] Stevenson, John J.: Notes on the coals of the Kanawha Valley, West Virginia. New York Lyceum Nat. Hist., Annals, vol. 10, 1874, pp. 271–277.

seam." The limestone overlying this coal in northern Ohio and Pennsylvania, as well as in the northern part of West Virginia, is greatly diminished in thickness, and is represented in this locality by calcareous shale only, containing a few nodules of limestone.

The Barren group has about 300 feet of thickness, and contains no workable coals; it varies but little in thickness from Pittsburgh to the Great Kanawha, running north and south.

The development of the Lower Coal group in this valley is extraordinary. In northern West Virginia the thickness is scarcely 200 feet; in the first geological district of Ohio it is rarely more than 300 feet; in either case containing only six or seven coal beds. In this valley it can be separated into two portions, the upper of which is no less than 900 feet thick, with fifteen beds of coal, and the other about the same thickness with two or three more coal beds. This development continues southwesterly until its thickness becomes about 2,500 feet in Tennessee.

The Mahoning sandstone, at the top of the group, is conspicuous in the river hills above Charleston, and holds a coal about midway, as in its northern extension in Ohio and Pennsylvania. It rests upon a variable bed of black flint, 5 to 12 feet thick. A few feet below the flint, and separated from it by shale sometimes arenaceous, is a coal partly cannel and partly bituminous, from 5 to 7 feet thick. It is regarded as identical with the Upper Freeport of Pennsylvania, and is known locally as the Stockton seam. Below this is a variable bed, at Cannelton a cannel of insignificant thickness, at Coalburg, it is the "Great Splint Coal," in some respects the most important bed along the river, and at the Kanawha Salines the place is occupied by several thin beds considerably separated. The bed is from 6 to 11 feet in thickness. In the thin layer of clay between the sandstones and coal are numerous impressions of *Lepidodendron* and *Sigillaria*, and there were remarkably fine leaf-scars of *Bothrodendron* discovered in one locality. The dark slate found in this bed is rich in bitumen. Five hundred and fifty feet below the Stockton seam, at Cannelton, is a bed of bituminous coal nearly 7 feet thick, known as the "Gas Coal," and below this coal a limestone was observed by Mr. Ridgway which he identified as the "Ferriferous" of Pennsylvania; if he is correct, the "Gas Coal" is probably the "Kittanning" of Pennsylvania.

J. J. Stevenson,[1] in 1874, presented a paper to the New York Lyceum of Natural History which embodies the results of an examination and comparison of the Ohio coals with those of Pennsylvania and West Virginia. The observations recorded cover only that portion of the field north of the Baltimore and Ohio Railroad in West Virginia and Ohio.

The limits of the Upper coals are first considered, and the conclusion reached that the Pittsburg coal, the base of the Upper Coal Measures, "once reached as far west as Sonora, 71 miles west from Wheeling, and to a point northward not less than 50 miles from that city, a tortuous boundary line connecting the two points."

Several sections from Ohio, West Virginia, and Pennsylvania are compared in order to ascertain their relations to each other. From this comparison it is found that only Coal VIII, VIIIa, VIIIb, and Coal XI can be seen in all the sections. Coal VIII is the Pittsburg, VIIIa appears as the Redstone, VIIIb as the Sewickley, while Coal XI is the Waynesburg.

[1] The Upper Coal Measures west of the Alleghany Mountains. New York Lyceum Nat. Hist., Annals, vol. 10, 1874, pp. 226–252, *pl. No. 12.*

A detailed description of each bed is then given. Coal VIII is regarded as the "parent bed of all the Upper coal in Ohio, remaining in existence as a flourishing swamp from the beginning of the epoch until its close."

The conditions of the Upper Coal Measures during deposition are treated at length, and the author is led to the following conclusions:

(1) The great bituminous trough west of the Alleghanies does not owe its basin shape primarily to the Appalachian Revolution.

(2) The Coal Measures of this basin were not united to those of Indiana and Illinois at any time posterior to the Lower Coal Measure epoch, and probably were always distinct.

(3) The Upper Coal Measures originally extended as far west as the Muskingum River, in Ohio.

(4) Throughout the Upper Coal Measure epoch the general condition was one of subsidence interrupted by longer or shorter intervals of repose. During subsidence the Pittsburg marsh crept up the shore, and at each of the longer intervals of repose pushed out seaward upon the advancing land, thus giving rise to the successive coal-beds of the upper coal measures.

(5) The Pittsburg marsh had its origin at the east.

I. C. White,[1] in 1874, before the same society, discussed the Coal Measures of western Virginia and Pennsylvania.

Two sections are given from the region under consideration, one from the eastern and one from the western flank of the "Dividing Ridge," an elevation between Morgantown and Wheeling, rising in Pennsylvania and extending south into West Virginia. The eastern section has a thickness of 800 feet in the Upper Barren group and 340 feet in the Upper Coal group; total thickness, 1,140 feet. The western section has a total of 822 feet, 544 feet in the Barren group and 278 of the Upper Coal. The sections show the well known fact that the coals and sandstones in this district thin out toward the west, while the limestones thicken up. The eastern section in Monongalia County is described in detail. The upper sandstones and shales are very coarse, showing that that they were deposited by pretty strong currents.

The different thicknesses and characters of the various coal beds are fully given.

In 1875 J. P. Lesley,[1] State geologist of Pennsylvania, prepared a brief digest of the state of classification and nomenclature of the rocks in New York, Ohio, and Pennsylvania at that time. The article might be quoted entire were there space, as no further condensation of the statements can be satisfactorily made; but a single scheme of equivalents will suffice to show the ideas of the author as to correlations at the beginning of the second survey of Pennsylvania. On page 97 we find—

[1] White, I. C.: Notes on the Upper Coal Measures of western Virginia and Pennsylvania. New York Lyceum Nat. Hist., Annals, vol. 11, 1874, pp. 46–57.

[2] Second Geol. Survey of Pennsylvania, 1874. Report of Progress, I: Note on the comparative geology of northeastern Ohio and northwestern Pennsylvania, and western New York, pp. 57–108.

The following scheme will show the old problem and its recent probable solution:

In Ohio.	In northwestern Pennsylvania.	In New York.	In middle Pennsylvania.
Conglomerate			Seral Cong., XII.
Cuyahoga shale			Umbral, XI.
Berea grit	Second Mountain sandstone	Conglomerate	Vespertine, X.
Bedford shales		Old Red sandstone (fish).	Ponent, IX.
Cleveland shales	Oil sands	Chemung	Vergent, VIII.
Erie shales		Portage	Vergent, VIII.
Huron shales		Hamilton	Cadent, VIII.
Corniferous		Upper Helderberg	Post Medidial, VIII.

The author states in a foot-note that he does not adopt "the general term Waverly sandstone formation of the Ohio Reports because of the controversies to which it has given rise." Also, that "Erie shales" should stand opposite both Chemung and Portage.

In a letter to the editor of the Journal,[1] dated June 26, 1875, Prof. Lesley speaks of Mr. Ashburner's discovery of what he calls "baby coal beds" in No. X, Upper or White Catskill, Rogers's Vespertine, in Huntingdon County, Pennsylvania, and considers it of great importance to American geology, as it explains the presence of the two coal beds on the face of the Alleghany Mountains and the fourteen small coal beds counted by Prof. Lesley years before, west of the Peak Mountain, in Wythe County, Virginia.

E. B. Andrews[2] compares the Ohio and West Virginia coal fields.

In this comparison the author takes the Pittsburg seam of coal as the base of measurement. This seam occupies the northern portion of the Alleghany coal field, and extends through Pennsylvania, Ohio, and West Virginia. From its outcrop to the base of the productive Coal Measures the intervals remain quite uniform. In Ohio Dr. Newberry's measurement is from 700 to 800 feet and Prof. H. D. Rogers's from 600 to 700 feet. But in the southern part of West Virginia the interval is much greater. Prof. Fontaine estimates 3,100 feet as the total thickness from the horizon of the Pittsburg seam to the base of the productive Coal Measures. This does not include the shales and the adjacent Lewisburg limestone, which are probably local. Hence we find about 2,400 feet more of Coal Measures in Virginia than in Ohio and Pennsylvania, and hence in West Virginia the series of productive Coal Measures make up a great geosynclinal, which is probably due to continental folding. The various coal seams, separated by small layers of shale, indicate that it was subject to alternate depression and elevation. In West Virginia, above the Pittsburg seam, over 1,200 feet of Coal Measures rock occur, showing several seams of

[1] Lesley, J. P.: Coal beds in the Subcarboniferous of Pennsylvania. Am. Jour. Sci., 3d ser., vol. 10, 1875, pp. 153, 154.

[2] A comparison between the Ohio and West Virginia sides of the Alleghany coal field. Proc. Am. Assoc., vol. 24, pt. 2, 1875, pp. 84–92.

coal. In the anthracite coal fields of Pennsylvania there is so much uncertainty as to the true equivalent of the Pittsburg seam that there is little chance for comparison.

Considerable difficulty arises in attempting to determine the exact situation of the Coal Measures conglomerate in the various States, nor is the Millstone grit of Indiana and Illinois synchronized, or its equivalent in the Alleghany field determined. In Arkansas a Millstone grit is reported, which Mr. Lesquereux declares is part of the coal formation. Mr. Dawson also describes a similar Millstone grit along the Bay of Fundy, but its relation to those of Great Britain or of the United States is not known.

E. B. Andrews,[1] in 1875, reported some interesting coal plants from Ohio:

> In Perry County, Ohio, a thin bituminous shale occurs at the base of the Ohio Coal Measures, containing pieces of plants similar to branches of Calamites, fish scales, and a small *Lingula*. Just above this layer is a thin stratum of shale carrying leaves of *Lepidodendron*. In the higher shales are found numerous ferns, etc. The plants found here were well marked Devonian types, with a few more recent than the Coal Measures, while those belonging to the Coal Measures are new species. A new species of *Archæopteris* is one of the Devonian forms: *Megalopteris* (Dawson) is another Devonian genus. One species of the genus was known in New Brunswick only, and described by Prof. Hartt as *Neuropteris dawsoni*. With these was found a fern of a new genus, of the order of the *Tæniopteridiæ*. The new Ohio genus the author calls *Orthogonopteris*. A new form of *Alethopteris* was noticed resembling the one found in the coal field of Cape Breton, but specifically different. Also a new *Asterophyllites*, *Hymenophyllites*, *Eremopteris*, and two species of *Lepidodendron*, with a few others. These are to be figured in the Ohio reports.

Mr. Lesley proposed a scheme of the formations[2] called "Table of rock formations, arranged in the order of the ages from above downwards, as they are recognized in America and according to the present state of our knowledge."[3]

Recent.
Glacial.
Tertiary.
Cretaceous.
New Red.
The Coal Measures, anthracite and bituminous.
The Great Conglomerate, No. XII, of Mount Pisgah, called by Rogers, "Seral."
Red Shale, No. XI, Umbral, around Mauch Chunk.
White Catskill, No. X (Vespertine), of the Second Mountain.
Red Catskill, No. IX (Old Red of England), Pocono Mountain.
Chemung shales (VIII, Cadent) holding the oil rocks.
Portage sands and shales (VIII, Vergent).
Hamilton black slates (VIII, Scalent); streaks of coal.
Upper Helderburg limestones, etc. (VIII, Postmeridial).
Oriskany sandstones (VII, Meridial), Stone Ridge, Lehigh Gap.
Lower Helderburg cement layers, etc.

---

[1] Andrews, E. B.: Notice of new and interesting coal plants from Ohio. Am. Assoc., Proc., vol. 24, pt. 2, 1875, pp. 106–109.

[2] *See Geol. Survey of Pennsylvania*, Report of Progress D on the Brown Hematite Ore Ranges of *Lehigh County*, by Frederick Prime, jr., 1874, p. 73.

[3] *Ibid., p. 63.*

In 1876 W. M. Fontaine[1] proposed the name of "Conglomerate series" for the strata in West Virginia which occupy the interval between the floor of the Productive Coal Measures and the Devonian (or lower productive coals and red shales of the Umbral). Important coals are said to occur in the equivalent of the Conglomerate series, and also well developed coals in the Vespertine of Montgomery County, Virginia, near White Sulphur Springs, West Virginia, etc.

D. D. Owen, nearly 20 years before, had recognized coals below the Conglomerate in Kentucky, although not in marketable quantities, and the Conglomerate was regarded by him as the base of the Coal Measures.

I. C. White,[2] in 1876, made some comments before the New York Lyceum on the Beaver County Coal Measures.

The line of section presented at the opening of this paper begins at the village of Homewood, in Beaver County, and follows the Beaver River to Rochester. The strata exposed extend from the Mahoning sandstone to the base of the Tionesta sandstone, dipping eastwardly at the rate of little more than 25 feet to the mile. The thickness of the Mahoning sandstone varies from 30 to 75 feet. It is usually a massive rock, but its composition is not persistent, sometimes it being merely a mass of shale.

Below it is the upper Freeport coal, of little importance, and then the Freeport limestone, a pure white limestone and very persistent. The bed of shale under this is fossiliferous, containing species of *Productus*, *Spirifer*, *Athyris*, etc. Then comes a thin seam of coal rich in vegetable remains, the lower Freeport coal, not workable, and the Kittanning coal, the most important bed in this part of the country, at one place yielding 200 tons daily.

To this succeeds the Ferriferous limestone, varying in thickness from 8 inches to 25 feet. It is richly fossiliferous in species of *Productus*, *Spirifer*, *Pleurotomaria*, etc. Shaly beds and thin beds of coal follow, one of the beds of shale containing many fossils, one stratum being made up almost entirely of *Aviculopecten whitei*, with *Spirorbis carbonarius* attached to these shells in vast numbers, the latter fossil occurring at this locality only.

The Tionesta sandstone is a very hard, coarse white rock. It is 50 feet above the river at Homewood, but passes under the river opposite New Brighton, 7 miles below.

Mr. Charles A. Young[3] describes the Conglomerate on New River as made of alternating sandstones and shales, the former numbering five, and the latter containing the workable coal seams. The total thickness is about 1,000 feet.

[1] Fontaine, William M.: The Conglomerate series of West Virginia. Am. Jour. Sci., 3d ser., vol. 2, 1876, pp. 276–284, 374–384; the Virginias, February, 1880, vol. 1, pp. 27–29.

[2] White, I. C.: Notes on the Coal Measures of Beaver County, Pennsylvania. N. Y. Lyceum of Nat. Hist., Annals, 1876, vol. 11, pp. 14–18.

[3] Young, Charles A.: On Conglomerate No. XII (in West Virginia). Philadelphia Acad. Sci. Proc., vol. 28, 1876, p. 262.

Mr. Andrew Roy,[1] in 1876, reported that the Mahoning Valley coal region lying in the northern part of the Ohio coal field belongs to the "lower coal of the Lewis No. 1 of the Ohio Geological Survey," and has a varying thickness from an inch to 6 or 7 feet. This deposit rests upon the "Waverly" sandstone, which is so folded as to form numerous troughs, in which the coal has reached its maximum thickness. The synclinals were probably formed by erosion anterior to the formation of the coal vegetation, and not by the mountain-building forces exhibited in the anthracite fields of Pennsylvania.

In the year 1876 there appeared, as one of the volumes of the Second Geological Survey of Pennsylvania, the "Historical Sketch of Geological Explorations in Pennsylvania and other States, by J. P. Lesley, the State geologist."[2] This was reprinted without revision in 1878. It contains so much of interest to the readers of this essay that I refer them to it without abstracting its contents.

Chapter I is entitled "Early Observations of the Geology of Pennsylvania."[3] Titles of papers and comments on some of them are given dating back to 1780.

Chapter II is entitled "The Geological Society of Pennsylvania; and what it did to bring about the first geological survey of the State."[4]

Chapter III, "A history of the first geological survey of Pennsylvania,"[5] an elaborate description of the "Final Report of 1858," occupying pages 134 to 197.

Chapter IV is "A sketch of the history of other State geological surveys in the United States, and of their relations to that of Pennsylvania."[6] The press of other duties prevented the author from completing this chapter; only one State, that of North Carolina, is discussed.

In these chapters may be seen an account of the development of the knowledge regarding the geology of Pennsylvania up to the close of the first survey and publication of the final report in 1858. The new survey, begun in 1874, in matters of correlation adopted the classification of the first survey, but modified and amplified its nomenclature.

With the opening of the Second Geological Survey of Pennsylvania, Mr. Franklin Platt was engaged as assistant to work up the bituminous coal fields of western Pennsylvania. As a working scheme of classification and nomenclature he modified the scheme of the first survey as published in the final report of 1858 to adapt it to results of the investigations of the year 1874, and published in Report[7] of Progress H the following scheme of Coal Measures and underlying formations:

---

[1] Roy, Andrew: The Mahoning Valley coal regions. Trans. Amer. Inst. Mining Eng., vol. 4, 1876, pp. 188–190.

[2] Geol. Survey of Pennsylvania, Rep. of Progress. Report A: A history of the first Geological Survey of Pennsylvania from 1856 to 1858, by J. P. Lesley; pp. 226. 1876.

[3] Pp. 3–28.

[4] Pp. 29–52.

[5] Pp. 53–197.

[6] Pp. 198–200.

[7] *Second Geol. Survey of* Pennsylvania, 1874. Report of Progress in the Clearfield and Jefferson *district of the bituminous coal* fields of western Pennsylvania, by Franklin Platt, Harrisburg, 1875.

THE COLUMN OF PALEOZOIC FORMATIONS.

Series.			
Monongahela	Upper Barren Measures.		
	(M) Brownsville (Washington) coal bed.		
	(L) Waynesburg coal bed.		
	(K) Sewickley coal bed.		
	(J) Redstone coal bed.		
	(I) Pittsburg coal bed.		
Conemaugh	Middle Barren Measures.		
	Mahoning sandstone.		
Alleghany	(E) Upper Freeport coal bed.		
	(D′) Middle Freeport coal bed.		
	Freeport limestone.		
	(D) Lower Freeport coal bed (Reynoldsville).		
	Freeport sandstone.		
	(C) Kittanning coal bed.		
	(B′) Ferriferous coal bed.		
	Ferriferous limestone.		
	(B) Clarion coal bed.		
	(A) Brookville coal bed.		
	Conglomerate	No. XII	(Seral.)
Shenango	Sharon coal beds	No. XI	(Umbral.)
	Red shale		
Catskill	New River coal beds	No. X	(Vespertine.)
	White sandstone		
Chemung	Olive shales		
Portage	Olive sandstone		(Vergent.)
Hamilton	Juniata coal beds	No. VIII	
	Black shales		(Cadent.)
Upper Helderberg	Corniferous limestone		(Postmeridial.)
Oriskany	White sandstone	No. VII	(Meridial.)
Lower Helderberg	Lewistown limestone	No. VI	(Premeridial.)
Waterlime	Cement layers		(Scalent.)
Clinton	Red shales and fossil ore	No. V	(Surgent.)
Medina	Red sandstone	No. IV	(Levant.)
Oneida	White sandstone		
Hudson River	Slates	No. III	(Matinal.)
Trenton	Limestone	No. II	
Calciferous	Dolomites	No. II	(Auroral.)
Potsdam	Sandstone	No. I	(Primal.)

In the first column the names below Shenango are those adopted by the New York geologists previous to 1843. The numbers in the third column are those adopted by the geologists of the first survey of Pennsylvania in the annual reports previous to 1842. The names in the fourth column are those of the final report of the first geological survey, by H. D. and W. B. Rogers, published in 1858. The letters A, B, C, D, E, applied to the coal beds of the Alleghany series are those adopted by Hodge and Lesley.[1]

In 1876 Franklin Platt described the geological column at Connellsville.[2]

The section is as follows, viz:

(1) The Upper (Monongahela) Coal Measures, including about 280 feet of slates, sandstones, shales, and limestones, and the "Great limestone" with the "Pittsburg coal bed" at the base.

(2) The Lower Barren Measures, including, besides shales and sandstones, the Pittsburg limestone, about 26 feet below the coal; Connellsville sandstones, 76 feet below the coal; and the Mahoning sandstone, 421 feet below the coal.

[1] Fifth Annual Report, 1841; Lesley's Manual of Coal, 1856; and H. D. Rogers' Annual Report, 1858.

[2] Second Geol. Surv. of Pennsylvania, Rept. of Progress L: Special Report on the coke manufacture of the Youghiogheny River Valley in Fayette and Westmoreland Counties, 1875, pp. 13–39.

(3) Lower or Alleghany River series, consisting of shales, coal beds, limestone, and ores, and down to the Conglomerate, No. XII.
(4) Ore beds of XI; limestones of XI.
(5) Catskill rocks, No. X, or Catskill gray sandstone.
(6) Chemung rocks No. VIII.

The means of correlation and identification were the "Pittsburg coal," distinguishing the base of the Upper Coal Measures, the "Mahoning sandstone," which is described as "the great key rock of the bituminous coal field in Pennsylvania, Ohio, West Virginia, and Kentucky. It was first best studied on the Mahoning River, in Jefferson County, and hence its name."[1]

This marks the base of the "Lower Barren Measures" and it puts on locally a thousand varying aspects, being coarse, pebbly, and massive, and again fine-grained, thin-bedded, and shaly." And at the base of the lower series is the "Conglomerate No. XII," which presents similar variations. It is the "Seral" Conglomerate of the first survey.

In 1877 Mr. Platt[2] published the following "Scheme of the measures" which "would be met with could a well be bored near Waynesburg, or on the highest geological land in Greene County:"[3]

1. The Monongahela River system:
   (*a*) Greene County group of Upper Barren Measures.
   (*b*) Washington County group of Upper Barren Measures.
   (*c*) Upper Productive Coal Measures.
2. The Alleghany River system:
   (*a*) Lower Barren Measures.
   (*b*) Mahoning sandstone.
   (*c*) Lower Productive Coal Measures.
3. The Kanawha River system:
   (*a*) Pottsville Conglomerate. } XII.
   (*b*) Kanawha Coal Measures. }
   (*c*) Mauch Chunk red shale.. } XI.
   (*d*) Mountain limestone ..... }
4. The New River system (of Lesley, not of Fontaine):
   (*a*) New River Coal Measures..... } X.
   (*b*) Pocono (Upper Catskill) sandstone. }
4. The Devonian system:
   (*a*) Catskill Old Red sandstone, IX.
   (*b*) Chemung sand and shales..... } VIII.
   (*c*) Portage shales and sands..... }
   (*d*) Hamilton { Genesee black shales... / Juniata Coal Measures. / Marcellus black shales. } VIII.
   (*e*) Upper Helderberg limestone... .... } VIII.
5. Upper Silurian system:
   (*a*) Oriskany sandstone, etc., to the Archean.

Four new names are noted in this list, "proposed by the present State geologist of Pennsylvania," viz:

Pottsville Conglomerate, for Rogers' "Seral," No. XII.
Mauch Chunk Red shale, for Rogers' "Umbral," No. IX.
Kanawha Coal Measures, for Fontaine's "New River" series.
Pocono sandstone, for Rogers' "Vespertine," No. X.

---

[1] Second Geol. Surv. of Pennsylvania, Rept. of Progress L. Special Report on the coke manufacture of the Youghiogheny River Valley in Fayette and Westmoreland Counties, 1875, 22.

[2] Geol. Survey of Pennsylvania, Rept. of Progress H²: Report on Cambria County, by F. and W. G. *Platt, pp. 194, 1877.*

[3] *Ibid., p. XXIII.*

The scheme of formations published in Report of Progress HH., 1875, is repeated, but with change in names, in Report HHH, 1877. In the preface of this report,[1] by J. P. Lesley, the following scheme of formations is given:

I. The Carboniferous system:
  1. Monongahela River coal series:
    Upper Barren Measures.
      (*a*) Greene County group.
      (*b*) Washington County group.
    Upper Productive Coal Measures.
  2. Alleghany River coal series:
    Lower Barren Measures.
    Lower Productive Coal Measures.
      (*a*) Freeport coal group.
      (*b*) Kittanning coal group.
      (*c*) Clarion coal group.
    Pottsville Conglomerate (Seral) XII
      (*d*) Sharon and Quinnemont coal group.
    Mauch Chunk red shale ..... } XI
    Mountain limestone ..... }
      (*e*) New River coal group.. }
    Pocono sandstone (Vespertine) (mountain sands) X
II. The Devonian system:
  1. Catskill sandstone (Old Red) (? Oil Sand group) IX
  2. Chemung sands and shales .....
  3. Portage shales and sands .....
  4. Hamilton formation .....
    Genesee black shales ..... } XIII
    Hamilton sandstones .....
      Juniata River coal group .....
    Marcellus black shales .....
  5. Upper Helderberg limestones .....
  6. Oriskany sandstone VII
III. The Silurian system.
  1. Lower Helderberg limestone VI

The name "Quinnemont beds" is here substituted for the name "Kanawha River system" of the former reports, because the latter name was found inapplicable.[2]

In the report on Indiana County[3] Mr. Platt notes the discovery of fossils in an exposure of the Mountain limestone on the bank of the Dunbar Creek, three of which were identified with species of the Chester group.[4]

This correlates the series XI, Mauch Chunk of Lesley, with the upper division of the Lower Carboniferous limestone series of the Mississippi Valley.

[1] Geol. Survey of Pennsylvania, Rept. of Progress H³. Report on Somerset County, by F. and W. G. Platt, pp. 348, 1877.
[2] See p. xxii.
[3] Geol. Survey of Pennsylvania, Rept. of Progress H⁴: Report on Indiana County, by W. G. Platt, pp. 316. 1878.
[4] Ibid., p. 60.

In 1876[1] Mr. Stevenson classified the formations of Greene and Washington Counties. In his classification the Waynesburg sandstone is made the base of the Upper Barren series.

This is divided into two groups, called the Washington County group and the Greene County group.

The first, or lower, includes the rocks from the Waynesburg sandstone to the Upper Washington limestone, inclusive. The second, or Greene County group, extends from the top of the Upper Washington limestone to the top of the series.

The second distinguishing horizon is the Pittsburg Coal Bed, and the series between it and the Waynesburg sandstone is the Upper Productive Coal series.

Below this the Lower Barren series is the name applied to all the rocks down to the Mahoning sandstone.

The rocks below the Mahoning sandstone are the Lower Productive Coal series, the bottom of which is not seen in the counties under examination.

Several local names are applied to the various strata presenting conspicuous exposures in these counties. These are not of importance for the purpose of this paper.

In 1877[2] the same author reported upon the rocks of Fayette and Westmoreland Counties.

In this classification the Waynesburg sandstone, the Pittsburg coal bed, the Mahoning sandstone, and the Pottsville (Seral) conglomerate form the conspicuous landmarks in the sections by means of which the four divisions of the coal measures are separated.

Below the Pottsville conglomerate the Umbral series of Rogers are recognized, and the author reports the probable identification of fossils from the limestones of this series in West Virginia with fossils of the Chester limestones of the Mississippi Valley.[3]

The Sharon coal group is placed in this series below the Pottsville conglomerate.[4]

The Pocono (Vespertine) rocks include the rocks of the district below the Umbral limestone.[5]

In the following year (1878) Mr. Stevenson's third report[6] was published. In this report are particularly discussed the rocks of the section in the Ligonier Valley, Fayette and Westmoreland Counties. As in his previous reports, Mr. Stevenson adopts in general the nomenclature and classification proposed in the first geological survey. In this and

[1] Geol. Survey of Pennsylvania, Rept. of Progress K: Report on Greene and Washington Counties, by J. J. Stevenson, pp. 419, 1876.

[2] Geol. Survey of Pennsylvania, Rept. of Progress K[4]: Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of Western Pennsylvania. By J. J. Stevenson, pp. 437. 1876.

[3] Ibid., pp. 102, 103.

[4] Ibid., p. 103.

[5] Ibid., p. 105.

[6] *Geol. Survey of Pennsylvania*, Rept. of Progress K[3]: Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of Western Pennsylvania. By J. J. Stevenson, pp. 331, 1877.

the second volume he adapts this nomenclature to that proposed by Mr. Lesley, as where he uses Pottsville Conglomerate for "Seral," Mauch Chunk Red Shale for "Umbral," Pocono sandstone for "Vespertine," etc.

Regarding the rocks underlying the Pocono sandstone, in the Fayette County sections, the author refers them to the Catskill "by direction of Prof. Lesley," but under protest.[1] In a paper in the American Journal of Science[2] he explained his reasons for this correlation. The outcrops in question in the river gaps through Laurel and Chestnut Ridges, Fayette County, are separated by many miles from other outcrops of the lower series, and the stratigraphic and lithologic characters do not furnish satisfactory means for determining the precise age of the lower beds. Fossils, however, found in the rocks below the characteristic Pocono sandstone were Devonian marine forms, the majority of them identical with species of the Chemung rocks of New York, two or three Hamilton species, and no species characteristic of typical Catskill rocks of New York. The author therefore concluded that the rocks were of Chemung age and "probably belong to the Lower Chemung."

In the closing chapter (XXII) of the report Mr. Stevenson gives some valuable "Notes on the Paleontology of Southwest Pennsylvania," giving a list of 55 Coal Measure fossils, 26 Lower Carboniferous, and 15 Devonian forms. In most of the rocks of the district the fossils are rare, but occasionally in the limestones and shaly beds sufficient fossils are obtained to satisfactorily determine the correlations.

Mr. Persifor Frazer,[3] in 1877, reported that a specimen of coal was given to him from a locality 18 miles east of Bath, West Virginia, and later another specimen from Bath, by Mr. Pendleton. Mr. Frazer thinks there are some reasons for ascribing the coal to an horizon below the Carboniferous series.

Mr. S. Fisher Morris[4] reported that the New River coal field has only two seams that are workable. Their position is "in the Conglomerate, No. XII, and hence they are called by Fontaine "Interconglomerate." The thickness of the Conglomerate series is about 1,450 feet.

In the report[5] on Lycoming and Sullivan counties, Messrs. Sherwood and Platt follow the established nomenclature, identifying the various stata from outcrop to outcrop mainly by stratigraphic methods.

In the sections traced by Mr. Sherwood "provisional limits" are recorded between the Catskill red sandstone and the Pocono gray sandstone, and between the latter and "Mauch Chunk red shale."

---

[1] Geol. Survey of Pennsylvania, Rept. of Progress K, p. 13.

[2] 3d ser., vol. 15, pp. 423–430.

[3] Frazer, Jr., Persifor: Anthracite from "Third Hill Mountain," West Virginia. Phila. Acad. Sci., Proc., vol. 29, 1877, pp. 16, 17, ½ p.

[4] Morris, S. Fisher: "The New River coal field of West Virginia." Trans. Amer. Inst. Min. Eng., vol. 8, 1879–1880, pp. 261–269.

[5] Geol. Survey of Pennsylvania, Rept. of Progress G². Geology of Lycoming and Sullivan Counties. I. Field notes, by Andrew Sherwood. II. Coal Basins, by Franklin Platt. 1880, pp. 268.

In this series no fossils appeared to help the correlations. The correlation of Chemung Measures was based upon the appearance of Devonian fossils, and in the strata where the fossiliferous beds were few and the red rock similar to those above was prominent the designation "Transition beds of Chemung into Catskill" is given.[1]

The report[2] on Potter County by the same authors, adds no new features to the general problem of correlation—the report consisting of detailed identification of the formations already classified and named.

In the report[3] on Jefferson County the main part of the volume is occupied with details of the township surveys. On pages XXVIII to XXXIV the author, Mr. W. G. Platt, attempted a grouping of the formations that had previously gone under local names. The Lower Productive Coal Measures, aggregating about 300 feet in this county, he divided into the *Freeport group*, the *Kittanning group*, and the *Clarion group*.

The Pottsville Conglomerate No. XII, 300 feet thick, is subdivided into

Homewood sandstones.
Mercer group of coals and sandstones.
Conoquenessing Upper sandstones.
Quakertown coal.
Conoquenessing Lower sandstones.
Sharon coal and shales.
Sharon conglomerate.

H. M. Chance,[4] in 1881, compared the Millstone grit of Pennsylvania with that of England. He said a survey of the Conglomerate No. XII (Millstone grit) in Pennsylvania by Messrs. Chance, Carll, and White, and of the same rock in Yorkshire, England, by Prof. Green and colleagues, led to the discovery of a striking similarity in the structure of the rock in the two regions.

A comparison of the nomenclature adopted by the two parties of geologists is given, from the Sharon through the Conoquenessing sandstones to the Homewood sandstone of Pennsylvania, and the Kinder Scout grit, coal, and Rough Rock of Yorkshire. Afterward, as the middle members in both localities were sometimes represented by a single rock and sometimes by several, a generalization was adopted by each party, the second and third grits of the Yorkshire formation being called the Middle grits, and the upper and lower Conoquenessing sandstones of Pennsylvania, the Conoquenessing group. In the modified nomenclature the Ohio or Sharon Conglomerate of Pennsylvania corresponds to the Kinder Scout or Lower grits of Yorkshire, and the Rough Rock or Topmost grits of the latter to the Homewood sandstone of the former.

[1] Geol. Survey of Pennsylvania, Rept. of Progress G³, p. 50.

[2] Geol. Survey of Pennsylvania, Rept. of Progress, G⁵. The Geology of Potter County, by Andrew Sherwood. Report on the Coal Fields, by Franklin Platt.

[3] Geol. Survey of Pennsylvania, Rept. of Progress H⁶: Report of Progress in Jefferson County, by W. G. Platt. 1880.

[4] *Chance, H. Martyn:* The Millstone grit in England and Pennsylvania; in Am. Jour. Sci., 3d ser., *vol. 21, 1881, pp. 134-135.*

The first report written by Mr. White was published in 1878.[1] He recognized the following formations in the district reported on, viz, Beaver, Alleghany, and part of Butler Counties.

Upper Productive Coal series, Pittsburg coal bed (only).

Lower Barren Measure series, including the measures from the base of the Pittsburg coal to and inclusive of the Mahoning (Lower Mahoning) Sandstone, an average of 600 feet.[2]

Lower Productive Coal series. From the base of the Barren Measures to the "Piedmont Sandstone" of Prof. Lesley, which the author regards the upper member of the Pottsville Conglomerate No. XII.[3] This is subdivided into Freeport group, Kittanning group, and Clarion group, 325 feet.

Beaver River series (J. P. Lesley). This was called by the author in MSS "Conglomerate series," thus identifying it with the series so called by Fontaine in West Virginia.[4]

In the typical section of the series along the Beaver River and the Conoquenessing Creek the series is as follows:

	Feet.
1. Piedmont [?], Upper Homewood Sandstone	75–155
2. Shales, inclosing sometimes a coal bed, iron ore, ? Mercer ? limestone, and coal	20– 80
3. [Pottsville Conglomerate] Conoquenessing sandstone; Massillon sandstone of Ohio:	
(*a*) Upper members	40– 50
(*b*) Middle members	35– 40
(*c*) Lower members	20– 25
4. Sharon shales; sometimes thin layers of coal	7

The name "Conoquenessing sandstone" was introduced for the first time in this report. It is regarded by the author as equivalent to the "Lower Pottsville Conglomerate."

Mr. Lesley, in a note in the chapter on the Beaver River group,[5] remarks that he foresees—

> The probability that the whole group of Pottsville (seral) Conglomerate rocks, containing as it does large and valuable beds of coal, will some day be considered as included in the series of the Lower Productive Coal Measures, as it certainly is in the Alleghany River series, and finally as the Conglomerate No. XII (whether called Seral Conglomerate, Pottsville Conglomerate, Piedmont sandstone and Pottsville Conglomerate, Upper and Lower Homewood sandstone, Homewood sandstone and Conoquenessing sandstone, Massillon sandstone, for by all these names has one or both of its principal members been designated) may be considered the base or bottom member of the Lower Productive Coal Measures as justly as the Mahoning sandstone is considered the bottom member of the Lower Barren Measures, the Connellsville sandstone the bottom member of the Upper Productive Coal Series, and the Waynesburgh sandstone the bottom member of the Upper Barren Measures.

In the Ohio correlations the classification of the Coal Measures was substantially that originally proposed by the Rogers brothers and elaborated by the second survey of Pennsylvania. So far as the correla-

[1] Geol. Survey of Pennsylvania, Rept. of Progress Q.: Report on Beaver, NW. Allegheny, and S. Butler Counties, by I. C. White, pp. 337. 1878.

[2] Ibid., p. 23, et seq.

[3] Ibid . p. 39, et seq.

[4] The conglomerate series of West Virginia, Am. Jour. Sci., vol. 11, 1876, pp. 276–284, 374–384.

[5] Ibid., pp. 65–66.

tions, strictly speaking, are concerned, this was the case down to details which were variable in the different counties of Pennsylvania. As to the classification, the separation of the Conglomerate series from the Lower Coal Measures was not found to express an actual change in nature of the formations in eastern Ohio; and as late as 1884 Mr. Orton, then State geologist, united these two, calling them both Lower Coal Measures.[1]

In the sixth volume[2] the Coal Measures are classified as Carboniferous, thus:[3]

		Feet.
Carboniferous	17. Upper Barren Coal Measures	500
	16. Upper Productive Coal Measures	200
	15. Lower Barren Coal Measures	500
	14. Lower Productive Coal Measures	250
	13. Conglomerate group	250

This is practically the Pennsylvanian classification.

In the results already discussed, coal beds, as lithologic formations, have been the chief means used in the classifying and correlating the Coal Measures.

Fossil plants served to distinguish the Carboniferous from the Triassic and the Cretaceous Coal Measures, but have not heretofore been of much use in subdividing the beds into groups.

In Virginia and West Virginia the character of the plants found in the Upper Barren Measures led Mr. Fontaine to correlate them with the Permian formations of Europe.

The report of his study of the plants and of Mr. White's study of the structure is given in Report PP of the Second Pennsylvania Survey.[4]

A brief account is given of the floras of the Vespertine group (Pocono formation), Conglomerate group (Pottsville formation), Lower Productive Coal Measures, particularly the Kittanning Coal and the Upper Freeport horizons, Lower Barren Measures, Upper Productive Coal Measures, including the Waynesburg coal beds and the Upper Barren Measures. The flora of the last formation, including the roof shales of the Waynesburg coal beds, is discussed at length, and the species described and figured, the authors reaching the conclusion that the "Upper Barrens of the Appalachian coal field are of Permian age."[5]

Most of the species described are from the roof of the Waynesburg coal, and the authors suggest that "perhaps it might be best to separate the roof shales of the Waynesburg coal and Waynesburg sandstone and consider them transition beds, and the strata overlying and including the great limestone below the Sewickley coal are to be considered strictly Permian."[6]

---

[1] Geol. Survey of Ohio, vol. 5, p. 10.

[2] Ibid., Economic Geology, vol. 6, 1888. By Edward Orton.

[3] Ibid., p. 3.

[4] The Permian or Upper Carboniferous Flora of West Virginia and SW. Pennsylvania, by Wm. M. Fontaine and I. C. White, 1880, pp. 143, Pls. XXXVIII.

[5] *Ibid., p. 119.*

[6] *Ibid., p. 120.*

The authors recognize as of Pocono age coal beds in numerous localities in Pennsylvania, Virginia, and West Virginia, and they correlate the Mauch Chunk formation, or "Subconglomerate," with the Chester and St. Louis limestone group of Illinois, Indiana, and Kentucky, the Waverly group of southern Ohio, and the Cuyahoga shale and Berea grit, of northern Ohio.[1]

It is not proposed here to discuss the value of fossil plants as a means of correlation. The whole subject of the classification, distribution, range and association of fossil plants is under investigation by an expert botanist.

Several interesting problems of correlation depend much upon the evidence of fossil plants: as the determination of the true relations of the arenaceous deposits between the marine Devonian and the Carboniferous formations of the Appalachian province, the correlation of the Upper Paleozoic formations of the Acadian province, and the differentiation of the Permian from the Upper Coal Measures of the Appalachian areas. One work, however, may be cited as an illustration of the kind of modifications in classification suggested by fossil botany. In the year 1880 the results of Mr. Leo Lesquereux's work on the fossil plants of the Coal Measures of Pennsylvania were published in Report P.[2] Several of the chapters, particularly those on stratigraphy, were edited by the State Geologist, J. P. Lesley.

The greater part of the work is devoted to descriptions of the plants. At the close of the volume of text a list is given of the "Literature of the United States Coal Flora" (including Devonian), with 145 titles. Under "General remarks," chapter 2 is entitled "On the geographical and stratigraphical distribution of the plants of Carboniferous age;"[3] and at its close a "Table of distribution" gives the vertical range and geographical distribution of 599 species of plants. The arrangement of the columns expressing vertical range and classification presents in a concise form the results of Mr. Lesquereux's long, exhaustive and most careful study of the paleozoic plants of the United States.

The following is the classification:[4]

I. PRE-CARBONIFEROUS.

1. *Devonian.*
   Chemung (top division of No. VIII)=Middle Devonian.
   Catskill (No. IX), Upper Devonian.

2. *Pocono Sandstone* (No. X), including, in Pennsylvania, Sideling Hill Tunnel, Huntingdon County: Red shale, below Pottsville (Mount Carbon); Lehigh Gap, below Mauch Chunk; banks of the Susquehanna, above Pittston; (Lewis Tunnel and New River group, West Virginia.)

[1] The Permian or Upper Carboniferous Flora of West Virginia and Southwestern Pennsylvania, pp. 626-627.

[2] Description of the Coal Flora of the Carboniferous formation in Pennsylvania and throughout the United States. Vol. 1, cellular cryptogamous plants, Fungi Thalassophytes Vol. 2, vascular cryptogamous plants, Calamaria, Filicacea (Ferns). By Leo Lesquereux, pp. 694, and atlas, 87 plates.

[3] Edited by J. P. L., pp. 617-635.

[4] Pp. 636-657.

3. *Subconglomerate:* Mauch Chunk, No. XI, including Fontaine's conglomerate series of West Virginia, and localities in Alabama, Tennessee, Arkansas, Illinois, Chester Group; Indiana, Chester Group; and *Megalopteris* beds of Ohio and Illinois.

4. *Interconglomerate,* No. XII, Campbell's Ledge, near Pittston, east Pennsylvania; Shamokin Gap, east Pennsylvania; Jackson Shaft bed, Ohio; Cuyahoga bed, Talmadge Summit beds, Ohio; Youngstown, Ohio.

II. COAL MEASURES PROPER.

1. *Anthracite fields.*

5. Beds A, B, and C, at Archibald, Carbondale, etc.
6. Beds D, E, F, at Pittston, Wilkes-Barre, Scranton, etc.
7. Bed G, Wilkes-Barre, etc.
8. Upper Anthracite (Salem, etc.).
9. Rhode Island, etc.

2. *Bituminous fields.*

10. Coal A, B, above the Conglomerate (both beds often united), at Murphysborough, Neeleyville, Marseilles, Colchester, Morris, Mazon Creek, Centralia Shaft, Vandalia, Illinois; at Burnt Branch of Caney, etc., Kentucky; at Massillon, Ohio.

11. Coal C (which is sometimes united to B), at Clinton, Missouri; Cannelton, west Pennsylvania.

12. Fourth Coal (under the Barren Measures), at Duquoin, St. John, Illinois; Nelsonville, Ohio; Coshocton, Ohio; Sullivan County, Indiana.

13. Upper Coal (top of the Barren Measures), at Pittsburg, Pennsylvania; Pomeroy, St. Clairsville, Barnsville, Ohio; Carmi, Illinois; Grayville and New Harmony, Indiana.

In this classification the base of the Pocono is regarded as the lowest formation of the Carboniferous system, although the line separating it from the Catskill below is stated to be "purely empirical."[1]

The Kinderhook Group of Illinois "is probably referable to the Pocono."[2]

J. P. Lesley, 1886, gave some valuable statistics regarding the Pittsburg coal region.[3]

The Pittsburg Coal Measures have an aggregate thickness of 2,000 feet, containing 15 persistent workable coal seams. Their outcrop lies in a northwest and southeast direction across the State, forming a series of concentric curves, due to the peculiar way in which the surface has been eroded. The Pittsburg seam is the fifth in descending order. It has been preserved from eroding effects in the southern part of the region only. The author sees no reason for disbelieving that this seam with its companions once extended into New York and northern Ohio, and even crossed Lake Erie and Lake Ontario into Canada, and he is firmly convinced that "they once had a quasi-continental outspread."

The Pittsburg seam has a thickness of 12 feet at Connellsville, Penn-

[1] Lesq., Descr. Coal Flora, p. 622.

[2] Ibid., p. 624.

[3] Lesley, J. P.: The Geology of the Pittsburg coal region. Am. Inst. Mining Eng., Trans., Vol. 14, 1886, pp. 618–656, plate.

sylvania, and 15 feet at George's Creek, in Maryland. At Pittsburg it is 8 feet thick, and its outcrop 350 feet above water level.

The Washington bed, also in the Upper Coal Measures, 150 feet above the Pittsburg seam, has a thickness in places of 11 feet, its average being only 3½ or 4 feet.

In the Lower Productive Measures occur the Freeport bed, having an average thickness of 4½ feet, and the Kittanning and Clarion beds.

The Upper Barren Measures are characterized by the absence of workable coal beds. They contain 17 different limestone beds. The most persistent is the Upper Washington limestone, which has an average thickness of 30 feet. These Measures also contain a number of sandstone strata, varying from 50 to 100 feet in thickness, and situated in the upper part of the series. They are not as persistent as the limestones already referred to. The thickness of this series is estimated at about 1,100 feet.

The Upper Productive Measures are also characterized by the predominance of limestone rocks, which form nearly one-fourth of the whole series. There is a great development of sandstones at the top, forming the cliffs along the river at Waynesburg. In this division occurs the Pittsburg coal bed.

The Pittsburg Barren Measures have an average thickness of 600 feet, and include four beds of massive sandstone: The Connellsville sandstone; the Morgantown sandstone, which is oil-bearing and 150 feet beneath the Pittsburg seam, and 50 feet thick; the Saltsburg sandstone; the Mahoning sandstone.

The limestones occur mainly under the Pittsburg coal seam and above the Connellsville sandstone. Two hundred and fifty feet below the former is the Crinoidal limestone, and 100 feet above the Mahoning sandstone is found the Black limestone. The coal of this division is of no commercial value.

In the Alleghany series the first geological survey recognized but six divisions, but the second geological survey found it necessary to subdivide each of the series into three parts. A curious feature of this series is that it contains cannel coal beds.

But one persistent limestone is recognized in this group, designated as the Ferriferous limestone, which has been used as a key for the location of the oil-sand deposits beneath. This is followed by the Pottsville Conglomerate (No. XII), composed chiefly of three massive sandstone subdivisons, small coal seams, and fossiliferous limestones; next lower is the Mauch Chunk Red shale (No. XI), containing the iron ores of Uniontown and the siliceous limestone so well developed at Blairsville and Trough Creek, Huntingdon County, Pennsylvania, and which to the south develops into the great Subcarboniferous limestone. It also appears in Ohio and Kentucky, and in the Mississippi Valley is known as the "Archimedes limestone."

The Mountain sandstone group (No. X), occurs about 760 feet below

the Pittsburg bed, where it has a thickness of 860 feet, and in Venango County of 650 feet. Its equivalent in Ohio and Kentucky is known as the "Knobstone formation."

Underlying these rocks is the oil-sand group, having a total thickness of 350 feet. The first oil-sand, known as the Gantz rock, was struck at Pittsburg, at 1,435 feet below low-water river level, and has a thickness of 112 feet. The second oil-sand is called the Fifty-foot rock, and the third (the Gordon rock) is 260 feet below the Gantz rock.

Concerning the Devonian rocks below the oil-sands little definite knowledge has been attained.

Frank A. Hill,[1] in 1887, made the following remarks about the correlation of the formation of the northern coal fields of Pennsylvania:

"The Northern coal fields are situated chiefly in Luzerne, Lackawanna, Susquehanna, and part of Wayne counties. "The Northern coal field" consists of a single curved, crescent-shaped basin, with its concave side facing northwest, and "locally divided into the Wyoming and Lackawanna valleys." The rock series consists, besides the coal beds, of shales, slates, sandstones, and conglomerates. The Pottsville conglomerate above the coal seams has an average thickness of 200 feet. The coal beds are so split up that in many parts of the valleys they bear different local names, suggesting no relationship whatever. In fact, so little is known concerning the coal beds, that it is at present impossible to make any definite statement concerning their identification and equivalency.

In 1888 Mr. J. J. Stevenson, as a member of the American committee, prepared a "Report on the Upper Paleozoic (Carbonic)," for the International Congress of Geologists, which contains the following classification of the Upper Carbonic:[2]

UPPER COAL MEASURES.

Synonyms and local subdivisions.

Pennsylvania, XIII in part, Monongahela series.	XVI, XV	Upper Barren group; Upper Productive group; Upper Productive Coal group.*	Greene group, Washington group — Permian.
Virginia and West Virginia.	XVI, XV	Upper Coal Measures.	
Ohio		Upper Coal Measures.	
Indiana		Merome Sandstone. Upper Coal Measures.	
Illinois, Iowa, Kansas, Missouri		Upper Coal Measures.	
Western region		Permo-Carbonic and Coal Measures in part.	
Nova Scotia		Permo-Carbonic and Upper Carbonic in part.	
New Brunswick		Permo-Carbonic.	
		Upper Coal Measures.	

[1] Hill, Frank A.: Geology and mining in the Northern coal field of Pennsylvania. Am. Inst. Mining Eng., Trans., Vol., 15; 1887 pp. 699–707.

[2] International Congress of Geologists, London session. Reports of the subcommittees appointed by the American committee from its own members, assisted by associates, for the fourth session of the Congress to be held in London, September 17, 1888. D. Report of the subcommittee on the Upper Paleozoic (Carbonic). J. J. Stevenson, reporter. Pp. D4–D7.

MIDDLE COAL MEASURES.

Synonyms.

Pennsylvania, XIII in part, Alleghany River series { Lower Barren group.... } XIV. / { Lower Productive group } XIII.

Virginia { XIV / XIII } Middle Coal Measures.

Ohio ..... } Barren Measures. / } Lower Coal Measures in part.

Indiana ..... } Lower Coal Measures.

Illinois ..... }

Iowa ..... } Middle Coal Measures. / } Lower Coal Measures in part.

Michigan ..... Coal Measures.

Mississippi ..... }

Alabama ..... } Coal Measures in part.

Tennessee ..... }

Missouri ..... }

Western region ..... Upper Carbonic in part, Carbonic in part.

Nova Scotia ..... }

New Brunswick ..... } Middle Coal formation.

Newfoundland ..... }

LOWER COAL MEASURES.

Synonyms and local subdivisions.

Pennsylvania, XII, Seral Conglomerate, Pottsville Conglomerate, Umbral in part.

Virginia and West Virginia, XII, Quinnimont group Lower Coal Measures.

Ohio ..... Lower Coal Measures in part.

Indiana ..... } Conglomerate or Millstone grit.

Illinois ..... }

Michigan ..... Parma Conglomerate.

Alabama ..... }

Mississippi ..... } Coal Measures in part.

Tennessee ..... }

Missouri ..... }

Nova Scotia ..... }

New Brunswick ..... } Millstone grit formation.

Newfoundland ..... }

CHAPTER V.

THE CONGLOMERATES AND LOWER CARBONIFEROUS FORMATIONS OF THE APPALACHIAN PROVINCE.

Below the Pennsylvania Coal Measure series there are several thousand feet of Conglomerates, sandstones and shales, with occasional beds of limestones, and in localities showing thin beds of coal, which have been referred to the Lower Carboniferous. They present such differences in their stratigraphy in different localities that considerable difficulty has been experienced in correlating their several members. In general they represent the Mississippian series of the interior, and in some of the limestones fossils have been found establishing closer correlation. But they rarely show any marine fossils and their classification has been made almost entirely upon lithologic and stratigraphic grounds. The Conglomerate at the top has been correlated with the Millstone grit and classified as the base of the Coal Measures. The lower formations were called "Umbral" and "Vespertine" by the early geologists of the Appalachian province, "Mauch Chunk" and "Pocono" by the Second Geological Survey of Pennsylvania, and "Greenbrier" and "Pocono," by Stevenson in 1888.

The Second Geological Survey of Pennsylvania, besides the elaboration of the Pennsylvania series of Coal Measures, did good service in differentiating the formations immediately below, which were called in H. D. Rogers's nomenclature, "Umbral and Vespertine (Nos. XI and X)."

Mr. I. C. White also took a conspicuous part in this work. He was the author of the volumes on Lawrence County,[1] on Mercer County,[2] and on Susquehanna and Wayne Counties,[3] on Pike and Monroe Counties,[4] and on "The Geology of the Susquehanna River region, in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland."[5] In these volumes, besides the detailed correlations of the outcrops of the several townships, constituting the bulk of the reports, there is the development of a systematic classification and nomenclature for the geological formations of the regions surveyed, which were chiefly of Lower Carboniferous and Upper Devonian age.

---

[1] Second Geol. Surv. of Pennsylvania. Rept. of Progress. Q^2. Report on Lawrence County, and special report on correlation of the Pennsylvania and Ohio coal beds. By I. C. White, 1879, pp. 336.

[2] Q^3. Report on Mercer County. By I. C. White, 1880, pp. 233.

[3] G^5. Report on Susquehanna and Wayne Counties. By I. C. White, pp. 243. 1881.

[4] G^6. Report on Pike and Monroe Counties. By I. C. White. Report on the Delaware and Lehigh Water gaps. By H. M. Chance, pp. 407. 1882.

[5] G^7. Report on Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland Counties, (*i. e., the parts lying outside* of the anthracite coal fields). By I. C. White, pp. 464. 1883.

In Report QQQ, 1880, the following are the chief members of the Conglomerate Measures (chapter v) as they appear in Mercer County:

Homewood sandstone.
Upper Mercer Iron Ore shales.
Mercer upper limestone (= "*Mahoning sandstone*," Rogers, 1858).
Mercer upper coal (= *Tionesta coal* of Lawrence County).
Mercer shales.
Mercer lower iron ore.
Mercer lower limestone.
Mercer lower coal.
Mercer lower ore shales.
Connoquenessing upper sandstone.
Quakertown over-shales and ore.
Quakertown coal bed.
Quakertown under-shales and ore.[1]
Connoquenessing lower sandstone.
Sharon coal riders.
Sharon upper shales and iron ore.
Sharon plant shales.
Sharon coal.
Sharon Conglomerate.[2]

In Report Q[4], 1881, the Sharon Conglomerate is said to be,

For the western and northern counties, the accepted representative of the whole or of the lower part of the "Ohio Conglomerate." In Warren and Venango Counties it is known under the name of "Garland Conglomerate." In McKean, Forest, Elk, Cameron, Clinton, and Potter Counties it is known as the "Olean Conglomerate." In Clarion, Butler, Mercer, Lawrence, and Beaver reports it is called the "Sharon Conglomerate." In the nomenclature of the oil drillers it is the "Second mountain sand."[3]

The formations next below the Sharon Conglomerate are called by Mr. White the "Subconglomerate formations."[4]

The name is applied to a series of deposits underlying the Sharon Conglomerate in Crawford and Erie Counties, and resting on the Venango oil sand group.

The Subconglomerate is subdivided into the following, viz:

	Feet.
Shenango group	75
Meadville group	205
Oil Lake group	162

The Shenango group consists of the following members:

Shenango shale.
Shenango sandstone.[5]

[1] "The Mountain limestone (Umbral, Mauch Chunk No. XI) or Maxville limestone, of southern Ohio, should be found here." p. 49.

[2] Called "Ohio Conglomerate" in QQ.

[3] Report Q[4], pp. 62, 63.

[4] These are well defined in chapters VII to XI, Report Q[4] 1881.

[5] This is the Ferriferous sandstone, Report QQ, p. 95, sub-Garland conglomerate of the oil region reports; sub-Olean conglomerate of McKean, etc., reports; upper Pocono sandstone (Vespertine) *No.* X; and it is the flat-pebble conglomerate first recognized as such by Mr. Carll (see p. 81)

The Meadville group consists of—

Meadville upper shales.
Meadville upper limestone.[1]
Meadville lower shales.
Sharpsville upper sandstone.
Meadville lower limestone.
Sharpsville lower sandstone.
Orangeville shales.

The Oil Lake group is correlated with the Berea grit of Ohio, the Pithole Grit of Venango, and the Pocono sandstone, No. X, of more eastern sections in Pennsylvania.[2] It is composed of the—

Corry sandstone (=Third Mountain sand of Venango).
Cussewago limestone.
Cussewago shales (=Bedford red shale formation of Ohio).
Cussewago sandstone.

Regarding the formations below this there was still (1881) considerable difference of opinion among the several members of the Second Survey of Pennsylvania. Mr. White, in Report QQQQ, correlated the outcrops of Erie and Crawford Counties as follows:

Venango oil sand group:
Venango upper sand (first oil sand).
Venango upper shale.
Venango middle sandstone (second oil sand).
Venango lower shales.
Venango lower sandstone.... { Le Bœuf conglomerate. / Panama conglomerate. / Third oil sand.

The author reported Chemung fossils from the Venango upper sand, the lower shales, and the lower sandstone.

The author correlated the Venango as "at least in part of Chemung age." He had identified Chemung fossils in the higher Riceville shales.[3] In a foot-note[4] he stated that he was "disposed to look upon the *Venango group* as Upper Chemung," and "on account of the fossils, I should prefer to call these [called Chemung in the text] Lower Chemung." The State geologist, however, objected to this interpretation and in the prefatory letter stated his objections. The substance of this objection is expressed in the following clause:

> Thus the matter stands at present. Geologists who insist on fossil forms will call the Venango group *Upper Chemung*, and will explain the McKean sections by a total disappearance of the oil sand in an increased mass of red beds. Geologists who insist upon lithological data will call the Venango group Catskill, or even Pocono, in spite of Chemung fossils.[5]

The latter course appears to have been Mr. White's preference. Below

[1] Containing fossils which the author concludes indicate correlation with the Lower Keokuk or Upper Burlington.
[2] See Q[4] chapter x, pp. 91–96. [3] Q[4], p. 97. [4] Q[4], p. 117. [5] Q[4], p. xi.

the Venango group in this report are the "Middle Devonian rocks (Chemung, Girard, Portage, No. VIII.)" They are composed of—

	Feet.
Chemung	325
Girard shales	225
Portage flags	475

Mr. White considered the interpretation of the Venango group in Erie and Crawford Counties as of great importance. He said:

> This identification [of the third Venango oil-sand with the LeBœuf conglomerate] I account the most important discovery to which my survey of the district has given rise.[1]

The importance of the correlation is further testified to by the State geologist, J. P. Lesley, who in his letter of transmission wrote:

> The cost of this survey has been justified merely by one result (setting aside the rest), namely, the determination by sufficient evidence that the *third oil sand* of Venango County is the quarry rock of Erie County, and that this deposit in crossing Erie County changes its character from a muddy sandstone in the western townships to a coarse gravel rock east of LeBœuf Creek, becoming the Panama conglomerate in the State of New York; everywhere charged with a peculiar group of fossil shells and seaweed, and with petroleum, which has evidently resulted from their decomposition.[2]

The method of this determination was in the first place physical and not by fossils. The average dip and direction of dip were ascertained by the comparison of altitudes of the third oil sand in the numerous wells. With this assumed rate of rise on going northward, outcrops were identified by their altitude; these were followed from ravine to ravine or quarry, and the rocks in the quarries were then defined, their fossils identified, and thus their position in the chronologic scale determined. Although the same method was practically used by both Mr. White and Mr. Carll, when their tracings of correlation had reached Chautauqua County the result was that Mr. White correlated the Panama conglomerate with the third oil sand of Venango County, while Mr. Carll placed it entirely below his Venango oil group.

The fact seems to be, as we review the records of the survey, that the data of lithologic character of rocks and of thickness of the deposits were so constantly variable that the "theory of persistent parallelism of strata" was little more than a theory, the exceptions to which were as numerous as the illustrations. It was a cut-and-try system of matching together innumerable sections, made up of irregular combinations of shales, sandstones, conglomerates, and limestone of various color, thickness, and texture. Whenever the gaps were over a mile or two long the adjustment of the theoretical dip, a few feet more or less to the mile, would enable the parallelism to fit any particular stratum in a given section. The fact that those who showed evidence of having noted the fossils, although they may not have identified them, were

[1] Q^4, p. 101. [2] Q^4, p. VII.

invariably nearer right than those who neglected them, strengthens the belief that the fossils, even in this case, were the most valuable means of correlation.

William M. Fontaine,[1] in 1877, published some notes on the Vespertine of the Virginias. The area occupied by the Vespertine in the two Virginias is limited by the main Alleghany in the northern and middle portions, and by Peter's and East River Mountains in the southern portion. The Vespertine rocks compose the middle portion of the main Alleghany from the Potomac to Pocahontas County. The author gives an account of the structure of the country and the geographical distribution of the Vespertine strata, as well as that of the underlying rocks, showing great distortion of the rocks and numerous faults. Two of the detached belts of Vespertine east of the limit mentioned are spoken of in detail, the first occurring on the east flank of the Alleghany Mountains, near White Sulphur Springs, containing coal strata and plant impressions, and showing the strata lying immediately above the Chemung, with the junction of this last with the lower portion of the Vespertine; the second belt more important and extended, about thirty miles east of the last, commencing in the northern part of Virginia, in Berkeley County, and extending south through the State. In the northern and middle portions the coal-bearing member of the Vespertine lies under the inverted massive sandstones of the lower member, and is found on the west side of the mountain, while in the southern part of the State, where the Vespertine strata are not inverted, the coal-bearing member lies on the southeastern face of the mountain. As all the strata, including the coals, thicken to the eastward, the Vespertine coal field must have extended much further in that direction than any remnant now to be seen, the belt of country over which well defined coal beds were formed being more than 300 miles long and 50 wide.

The author considers the most natural upper boundary of the Vespertine in the Virginias to be the base of the "Lewisburg limestone" (p. 43), which he correlates with the St. Louis and Chester groups (p. 44).

The Vespertine strata on Greenbrier River are described, the red upper member attaining a thickness of 250 feet, but thinning out to the north; the middle member, 290 feet thick, having about 70 feet at the top of bluish gray sandstone overlying 40 feet of thinly bedded gray flags, with fully 50 thin strings of carbonaceous matter distributed through them, but with a considerable coal bed a little farther north. Above this carbonaceous portion are 120 feet of firm gray and brownish sandstones, and then 40 feet of very flaggy, gray, soft sandstones and shales, with some layers of fissile black shale containing indistinct vegetable impressions, mostly leaves of *Lepidodendra*. At the base are 20 feet of dark gray, compact, fine-grained sandstone.

At Lewis tunnel the base of the Vespertine shows a rock not brought up at Greenbrier River; a white, pebbly, highly siliceous sandstone, 60

[1] *Fontaine, William M.* Notes on the Vespertine strata of Virginia and West Virginia. Am. Jour. Sci., 3d ser., 1877, vol. 13, pp. 37–48, 115–123.

feet in thickness, and one of the most persistent and characteristic members of the Vespertine. With this should probably be counted 500 feet of underlying, more argillaceous flags, giving a total of 560 feet for the lower member of the strata in this section. The middle member, 350 feet thick, is characterized by the predominance of gray sandstones containing coal. The upper member consists almost entirely of red marlites, with a thickness of about 250 feet, giving the group a total thickness of 1,160 feet. Although the author does not altogether agree with Prof. Rogers in his measurements, he thinks that they show a considerable thickening of the red overlying strata to the south.

In Augusta County there is great contortion and disturbance of the strata. To the west of this they have suffered much from erosion, and show only the lower and middle members. The Vespertine of Montgomery County is treated at great length. The two areas of Brush Mountain and Price's Mountain, separated from each other by a narrow belt of Lower Silurian limestone, are described, and a detailed section of the lower and middle members of the series exposed at Brush Mountain is given. The lower member shows a thickness of 930 feet, and the middle member is 670 feet thick, but the upper red member is much better displayed at Price's Mountain, where it has a thickness of 1,090 feet.

The conclusion drawn by the author from the facts stated is "that there has been a very marked thickening of the Vespertine as we proceed from north to south through the State, accompanied by an increase in the amount of coal contained in it. This increase seems to be largely at the expense of the supposed Catskill beds. It is in conformity with a law of increase which holds good for all the strata from the Devonian to, and including, the Lower Barren Measures of the Upper Coals."[1]

But few species of plants were found, but these were marked by the great number of individuals exhibited. The most important were forms of *Lepidodendron*, *Palæopteris*, and *Triphyllopteris*, and one specimen of *Neuropteris*.

In 1878,[2] C. A. Ashburner, reported the following section across southern Huntingdon County.[3]

	Feet.
XIII. Carboniferous, Lower Productive Co al Measures, Alleghany River series	256
XII. Pottsville Conglomerate (= Seral Conglomerate)	280
XI. Mauch Chunk (Umbral) red shale and Mountain limestone	
XI*c*. Upper Mauch Chunk shales and sandstones	910
XI*b*. Mountain limestone	49
("Lewisburg limestone" of the Greenbrier region in Virginia; St. Louis and Chester limestone of the Mississippi Valley.)	
XI*a*. Lower shales and sandstones	111

[1] P. 122.

[2] Geol. Survey of Pennsylvania, Report of Progress, F: Report on the Juniata River district in Mifflin, Snyder, and Huntingdon Counties, by J. H. Dewees; and on the Aughwick Valley and East Broad Top region, in Huntingdon County, by C. A. Ashburner, 1878, pp. 305.

[3] Report of Progress, F, pp. 184–260.

X. Pocono (Vespertine) sandstone.			
	Xd. Upper gray sandstone group	610	
	Xc. New River coal series	313	2,133
	Xb. Middle Conglomerate group	340	
	Xa. Lower green sandstone group	830	
IX. Catskill (Ponent) Old Red sandstone.			
VIII. Lower Devonian series.			
VIII. D. Chemung	b Transition beds		90
	a Olive (Vergent) shales		860
VIII. C. Portage (Vergent flags)			1,450
VIII. B. Hamilton	c Genesee (Cadent, upper) slates		325
	b Hamilton's Cadent shale		635
	a Marcellus (Cadent, lower) black slate		875
VIII. A. Upper Helderberg Corniferous (Postmeridian) limestone			60
VII. Oriskany (Meridian) sandstone			58

Etc. through the Lower Paleozoic.

In 1880 Mr. Ashburner completed and published his report[1] on the geology of McKean County. During the reconnoissance survey in 1876 he had collected a large number of fossil specimens. He was unable to arrive at any "satisfactory conclusions as to a systematic division of the strata." He "finally decided to group the strata by a study of their lithology, and on this basis to seek to make a connection with sections in those portions of the State where the structure had been clearly defined."[2] As a result of his studies he published, as one of the sheets, Plate XI.[3]

During the construction of this sheet he indicated the groups of rocks by letters "A, B, C." After it was finished he determined, by comparison with the sections of adjoining counties, the correlations, and the highest, A, he called "Pocono," B "Catskill," and C "Chemung."

In this report the Olean Conglomerate formed the conspicuous base of the Pottsville Conglomerate series, or No. XII of the old classification. This was, for Ashburner, the base of the Coal Measures and was the equivalent of the Ohio Conglomerate.[4]

Below this conglomerate he reported a series of 500 to 800 feet of rocks which he was obliged to correlate with the Mauch Chunk shales (XI), Pocono sandstone (X), and Red Catskill (IX) of other parts of the State; but the few fossils obtained appeared to him so mingled and to range so throughout the whole series that he could not subdivide them satisfactorily. Eighteen species, he reported, "are identical with characteristic Waverly species," "seven with Chemung species," and he says:

> I am thoroughly convinced that these rocks hold a fauna which is essentially a unit incapable of subdivision, and that this fauna is decidedly of a Subcarboniferous age.[5]

[1] Geol. Survey of Pennsylvania, Report of Progress R: Report on McKean County, and its geological connections with Cameron, Elk, and Forest Counties, by C. A. Ashburner; pp. 371, 1880.

[2] Report of Progress R., page 29; also see page 292.

[3] A series of columnar sections constructed from surface observations and the records of eleven oil wells situated between Bradford, in McKean County, and Ridgeway, in Elk County, showing the relation of the Lower Carboniferous coal beds to the Bradford oil-producing sand and the thickening of the subconglomerate rocks. J. P. Lesley, State geologist; Chas. A. Ashburner, assistant geologist; *A. W. Sheafer, aid.*

[4] *Report of Progress R, pp. 56, 62.*

[5] *Ibid., p. 30.*

In western Pennsylvania the development of the oil industry furnished a means of geological correlation not before accessible. The great number of oil wells distributed over large areas in western Pennsylvania (and since then wells have been drilled in almost every State in the Union), where the records were preserved and studied, furnished data of levels attained by particular formations under the surface.

Mr. John F. Carll, one of the geologists of the second geological survey of Pennsylvania, collected these data, coordinated them, and elaborated from the records a classification of the formations. His results are contained in Reports of Progress I, II, III, and IIII.[1] In the first of these reports (I) the origin of the name *oil sands* is explained. In the early drilling for oil in Venango County, the drillers, recognizing these sands in their wells in Oil Creek, distinguished them by the term *oil sands*. When the higher ground was perforated the sandstone layers supposed to lie above the horizon of the three oil sands of Oil Creek were called "mountain sands."

Thus it came about that the series of shales and sandstones, about 350 or 400 feet thick, containing the three petroleum-bearing sands of Oil Creek, Venango County, were named the "Petroleum Measures of Venango, or Division of the Three Sands or Oil-sand group," and the rocks above, up to the base of the Conglomerate No. XII, were called the "Mountain sand group or Barren oil measures."

In this report the following equivalences were proposed:

First mountain sand = Upper Berea grit, No. X.
Second mountain sand = Lower Berea grit?

The fact of the conspicuous development of the three sand layers in the wells of Venango County suggested the name "Venango oil-sand group," which was definitely proposed and defended by Mr. Carll in his third report.[2]

Prof. Lesley, in his letter of transmission, says of this report:

> The main feature of the report is the settlement of the true character of the Venango oil-sand group as a distinct and separate deposit, with characteristic marks distinguishing it from the Paleozoic formations of a preceding and a succeeding age; the differentiation of the group into three principal and other subordinate layers of gravelly sand, holding more or less oil and gas; the local variability of these sands; their singular persistency beneath long and narrow belts of country; their change into barren shales elsewhere, and their independence of other oil-bearing sands and shales of an earlier and of a later date.[3]

Mr. Carll proposed the name "Garland Conglomerate" for the lowest member of the Carboniferous Conglomerate series in the part of the

[1] I. Geol. Survey of Pennsylvania, Rept. of Progress: I. Report on Venango County, by J. F. Carll; the geology around Warren, by F. A. Randall; notes on the comparative geology of northeastern Ohio, northwestern Pennsylvania, and western New York, by J. P. Lesley. 1875. pp. 127.

II. Report of oil well records and levels in Venango, Warren, Crawford, Clarion, Armstrong, Butler, etc., by J. F. Carll, 1877. pp. 398.

III. Report on the Venango, Warren, Clarion, and Butler oil regions, by J. F. Carll, pp. 482. 1880.

IIII. Report on Warren County, by J. F. Carll, pp. 439. 1883.

[2] I³, p. 130.

[3] Rept. of Progress, I³, pp. vi, vii.

State studied by him.[1] He correlated it with the Olean Conglomerate of McKean County, the Sharon Conglomerate of Mercer County, the Ohio Conglomerate of Ohio, and the Second Mountain sand of the oil wells.

"Sub-Garland sandstone" was used for Mr. Ashburner's "Sub-olean" and Mr. White's "Shenango sandstone." In chapter VI the author, by the application of the methods of correlation suggested by his experience with oil well records, determined the Panama Conglomerate of Chautauqua County, New York, first, to be older than the Olean or Garland Conglomerate; second, to be neither of the Venango oil sands; and third, to be of Chemung age by lying below the horizon of the Venango oil sand group.[2]

He pointed out the important distinction that the pebbles of the Panama Conglomerates are almost always lentiform or flat in shape, while the pebbles of the higher Carboniferous Conglomerates are irregularly spheroidal.[3]

By the same methods he argued that the place of the Salamanca Conglomerate is above the Panama Conglomerate.[4] Again, he correlated the "First Mountain sand" with the Conoquenessing sandstone of Butler County and the Kinzua Creek sandstone of McKean County; the "Second Mountain sand" is a synonym for the Garland Conglomerate; for the "Third Mountain sand" of the earlier reports of the oil men, he proposed the name "Pithole grit," which he considered equivalent to the Berea grit of Ohio.[5]

The author prepared the following generalized section of the formation from the Upper Barren Coal series of Greene County, Pennsylvania, down to the Corniferous limestone, which will show his interpretation of the series as the result of a detailed study of oil well records:[6]

		Feet.
1.	Upper Barren Coal Measures, B. Greene County group, from top to Washington upper limestone... Upper Barren Coal Measures, A. Washington County group, extending to Waynesburg sandstone..	600 350
2.	Upper Productive Coal Measures, to base of Pittsburg coal.....	475
3.	Lower Barren Coal Measures, to top of Mahoning sandstone.....	500
4.	Lower Productive Coal Measures, to top of Conglomerate No. XII.....	400
5.	Mountain Sand series, to base of Olean-Garland-Ohio Conglomerate....	∓375
6.	Crawford shales, to top of Venango Oil group	∓450
7.	Venango Oil group, from top of "First Oil Sand" to bottom of the "Third Oil Sand".....	∓350
8.	Interval between the Venango Oil group and the Warren Oil group....	±300
9.	Warren Oil group	300
10.	Interval.....	400
11.	"Bradford Third Sand".....	20 to 80
12.	Interval between the Bradford "Third Sand" and the Corniferous limestone, commencing in the Chemung and including the Portage and Hamilton groups of the New York Geological Survey.....	1,600
13.	Corniferous limestone	

[1] *Rept. of Progress*, I[4] p. 13. [2] Ibid., p. 77. [3] Ibid., p. 60. [4] Ibid., p. 79.
[5] *Ibid., p. 82, and chapter* 8, p. 91. [6] Rept. of Progress, III, pp. 156–164.

Mr. Carll further discussed the Conglomerates in his report on Warren County.[1]

The Pottsville Conglomerate No. 12 was subdivided into upper, middle, and lower beds, called "Johnson's Run rocks," "Kinzua Creek sandstone," and "Olean Conglomerate."

He correlated these with "Homewood sandstone," "Conoquenessing sandstone," and "Sharon Conglomerate" of the reports Q, Q^2, Q^3, and Q^4. And he proposed to drop the name "Garland Conglomerate" as a synonym for the Olean Conglomerate of Mr. Ashburner's report on McKean County.[2]

In the chapter on the Panama Conglomerate Mr. Carll defended his former opinion that the Panama Conglomerate is not equivalent to any member of the Venango group but stratigraphically is below it, against the view published by Mr. White in Q^4, that the Panama represents the Third oil sand of the Venango oil group. Mr. White claimed the equivalency upon evidence of fossils. Mr. Carll objected to the recognition of the Venango group as Chemung, on account of the absence of any Chemung fossils in any of the members of that group as seen in the Venango County sections.[3] Mr. Carll's method was based upon the theory of the persistent parallelism of strata. While for short distances and in certain directions no doubt the dominant character of the strata could be traced, often this theory utterly failed him, as he confessed in a foot-note on page 205, where, discussing the relations of the sub-Olean and Salamanca Conglomerate across Warren County, he says:[4]

> Sometimes no trace of the particular sand rock sought for could be found in *proper place*, and instead of it other massive pebbly strata would obtrude themselves, 100 feet too high or 100 feet too low to fit into the places where, according to our theory of persistent parallelism of strata, they ought to belong.

In report V[5] Mr. Chance discusses the "geology of northern Butler and parts of Beaver, Lawrence, and Mercer Counties." Aside from the detailed geology the most important contribution toward the development of the classification of the Pennsylvania rocks was his analysis of the Coal Measure Conglomerate, No. XII. The following table exhibits it:[6]

Coal Measure Conglomerate, No. XII. =Beaver River series.	Homewood Sandstone. Mercer group, coals. Conoquenessing group, sandstone. Sharon group, coal and shales. Ohio Conglomerate.

[1] Rept. of Progress I^4, 1883.
[2] Ibid., p. 185.
[3] Ibid., p. 195, et seq.
[4] Ibid., p. 205, foot-note.
[5] Geol. Survey of Pennsylvania, Report of Progress V. Report on northern Butler County; and (Part 2) special report on the Beaver and Shenango River Coal Measures, by H. M. Chance, 1879, pp. 248.
[6] Ibid., p. 188.

Another table shows the difference between his interpretation and that of Mr. Carll:

	Feet.		
Homewood Sandstone	30	No. XII, according to Mr. Chance.	
Mercer group	30	Feet.	
Connoquenessing group	155	265	
Sharon group	10		435 feet. No. XII, according to Mr. Carll.
Sharon Conglomerate (Ohio Conglomerate)	40		
Sharon upper shales	30		
Sharon upper sandstone	15	170	
Sharon middle shales	75		
Sharon lower sandstone	50		

	Feet.
Crawford upper (Cuyahoga) shales	135
Berea grit (Third Mountain sand of oil men, Carll)	75
Crawford lower (Bedford red) shales	--

The last three members of this table, classed together, were called "Crawford shale group" by J. P. Lesley.[1]

In the Report of Progress, G⁴,[2] Mr. H. Martin Chance published as Part Second, "A Special Study of the Carboniferous and Devonian strata along the West Branch of the Susquehanna River."[3] At the time this report was written the Coal Measures series had been fairly well studied, the Conglomerate as a base was established, and the eastern section had been particularly well surveyed, classified, and compared with that of Ohio. The northwestern sections of the State had been examined and great difficulties had been found in identifying the various members.

Dr. Newberry, in the third volume of the Geology of Ohio, had reported "that the Vespertine connects throughout this gap with the Waverly, but the Umbral and Catskill do not reach Ohio."

Mr. Chance says that—

> The Mauch Chunk red shale, No. XI, and the Red Catskill, No. IX, diminish in thickness rapidly from the Alleghany Mountains westward, so that in a few miles the latter entirely disappears; whereas the Pocono (Vespertine, No. X) thins gradually for a few miles, then maintains a nearly constant thickness for 90 miles, when it rapidly loses its lower half by a rise in the Chemung floor at the oil-sand shore line and again stretches away to the west, with a nearly constant thickness, for 100 miles or more.
>
> Among other causes productive of erroneous identifications in the northwestern counties, insufficient paleontological data may be mentioned. The lines of demarkation between Subcarboniferous and Catskill and between Catskill and Chemung fossil horizons are not uniformly drawn by paleontologists, and as—from the conditions essential to the growth of shellfish—it seems certain that there must (at some points) be an overlapping of the fossil fauna of one formation into that above it, the structuralist can not accept unquestioningly an identification supported by paleontological evidence alone.

His correlations are well expressed in detail in a "Table showing the

[1] [4]. See foot-note, p. 224.

[2] Geol. Survey of Pennsylvania. Report on Clinton County, by H. M. Chance; including a description of the Renovo coal basin, by C. A. Ashburner; and notes on the Tangascootac coal basin, by F. Platt, pp. 183, 1880.

[3] *Ibid.*, pp. 79–174.

proposed nomenclature of the Carboniferous and Devonian rocks of eastern Pennsylvania and Ohio."

	Eastern Pennsylvania.		Western Pennsylvania.	Ohio.
Carb	XIII	Coal Measures	Coal Measures	Coal Measures.
	XII	Conglomerate	Conglomerate series	Sandstone and shale with coals 1, 2, 3.
Subcarb.	XI	Mauch Chunk red shale	Red or dark shales.	
	X	Pocono sandstone	Upper (gray) Pocono	Cuyahoga and Berea grit.
			Lower (red) Pocono=oil-sand group.	Bedford shale. Cleveland shale.
Devonian	IX	Catskill	Absent	Absent.
	VIII	Chemung	Chemung	Erie shales. Huron shales.
		Portage	Portage.	
		Hamilton	Hamilton (?)	
		Corniferous lime-stone.	Corniferous	Corniferous lime-stone.

In order to explain the difficulties in correlating the deposits below the great Conglomerate, No. XII, Mr. Chance assumed that there was a basin during the deposition of the Catskill rocks, the western limits of which swept approximately through Potter, Cameron, Elk, Jefferson, Armstrong, and Westmoreland Counties; that along this line, or somewhat westward of it, a sudden rising into shallow water, or to shore line conditions, prevailed in the Catskill and Pocono time. This explains, as he thinks, the accumulation of oil-sands along such a shallow bottom, while further out the Catskill deposits were forming.[1]

Mr. Stevenson,[2] in 1887, presented some new views regarding the correlation of the Umbral and Vespertine in the southern extension of the Appalachian province. He stated that Prof. Roger's division of the Lower Carboniferous into Umbral and Vespertine, seems correct for the eastern side of the Appalachian area, but in southern Pennsylvania and Virginia there are variations worthy of study.

The Umbral deposits in Pennsylvania consist of red shales and shaly sandstones, and were afterward called by Prof. Lesley the "Mauch Chunk."

The limestones first noticed in Maryland increase rapidly in thickness westwardly.

The Vespertine consists of sandstone and shales, with occasional coal seams, and varies in thickness from 1,300 feet in Huntingdon County to 400 feet in Fayette County.

Owing to the faulted condition of the rocks in southwest Virginia, good sections of Lower Carboniferous rocks are shown from the Tennessee line to Giles County. The rocks do not change materially until we come within 75 miles of the Tennessee line. In this direction the Vespertine thins out more rapidly than the Umbral rocks, which in Pulaski and Bland Counties contain streaks of coal. In Smyth County,

[1] A diagram is given illustrating this view on p. 114 of the Report.

[2] Stevenson, J. J.: Notes on the Lower Carboniferous groups along the easterly side of the Appalachian area in Pennsylvania and the Virginias. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 37-44.

the Umbral, as well as the Vespertine, is scarcely noticeable, while the increasing limestones form the most important feature.

The Umbral of Pennsylvania, Maryland, and the Virginias is equivalent to the Chester and St. Louis groups of the Mississippi Valley, and it may include the Keokuk; while in the Vespertine must be sought the equivalents of the Burlington, and possibly of the Kinderhook.

In 1888 Mr. Stevenson, as one of the members of the American committee, prepared a report on the Upper Paleozoic (Carbonic) for the International Congress of Geologists. In this report the classification and synonomy of the Lower Carbonic is given as follows:[1]

GREENBRIER.

Synonyms and local subdivisions.

Pennsylvania XI, Umbral, most of; Mauch Chunk, most of; Shenango shale?
Ohio ... { Maxville limestone.. } Waverly group, in part.
{ Logan series ..... }
Virginia XI ..... Greenbrier group.
Tennessee.. } ..... { Mountain limestone.
Alabama... } ..... { Siliceous group.
Indiana ..... Mountain limestone.
Michigan.. } ..... { Chester group.
Illinois.... } { St. Louis group.
Iowa..... } { Keokuk group.
Missouri .. }
Nova Scotia..... }
New Brunswick.. } Windsor group.
Newfoundland ... }

POCONO.

Synonyms and local subdivisions.

Pennsylvania X, Vespertine, Pocono ..... { Shenango group.
{ Meadville group.
{ Oil Creek group, in part.
Virginia X ..... New River series.
Ohio: Waverly group, in part ..... { Cuyahoga shale.
{ Berea shale and grit.
{ Bedford shale.
{ Cleveland shale.
Tennessee } ..... Absent, or represented by the lowest beds of the Siliceous group.
Alabama. }
Indiana ..... Knobstone group, in part.
Illinois ..... Burlington group.
Iowa ..... Kinderhook group.
Michigan ..... { Michigan salt group.
{ Marshall group.
New York ..... Upper part of the Catskill gray sandstones.
Nova Scotia ..... Horton series.
Eastern Quebec ..... Bonaventure series.

[1] See Report, D, pp. 7, 8.

CHAPTER VI.

THE CHEMUNG-CATSKILL PROBLEM: THE HISTORY OF THE DISCUSSIONS CONCERNING THE CORRELATION OF THE CHEMUNG AND CATSKILL FORMATIONS IN THE NORTHERN PART OF THE APPALACHIAN PROVINCE.

In the year 1862 the discovery by Mr. J. M. Way, in the rocks of Franklin, Delaware County, New York, of fish bones, in association with Chemung fossils, raised doubt as to the validity of the correlation of the deposits. The rocks had previously been considered as Catskill, or Old Red sandstone. The fish remains discovered were regarded as characteristic fossils of the Catskill group. The marine fossils found in the same rocks had been regarded as typical Chemung fossils.

Col. E. Jewett, then curator of the State Museum at Albany, announced that "From my investigations I believe there is no Old Red sandstone in this State."[1] The letter communicating this determination was dated "Albany, September 20, 1862."

The same facts led Mr. James Hall to the following judgment:

> Late investigations, combined with those heretofore made, have forced upon me the conviction that the greater part of the area colored on the geological map of New York as *Catskill group*, is in fact occupied by the Portage and Chemung.[2]

Again—

> Until we ascend the slopes of the Catskill Mountains and rise to an elevation of at least 2,000 feet above tide water, we find no rocks of newer age than the Chemung.[3]

And again—

> It now becomes necessary to restrict the term *Catskill group* to the beds formerly known as x and xi of the Pennsylvania survey.[4]

This announcement, as Alexander Winchell wrote[5] in a letter to James D. Dana, dated December 10, 1862, produced "a sensation among geologists," and led to discussions extending over a number of years.

In this letter Winchell spoke of Jewett's announcement[6] of disbelief in the existence of the Catskill group in the State of New York, and recalled his own disbelief in its existence as a distinct group, and his

[1] Am. Jour. Sci., 2d ser., vol. 34, p. 418. Also 15th Ann. Rep. State Cabinet of Nat. Hist., Albany, 1862, p. 198.

[2] On the Catskill group of New York, by Prof. James Hall. A letter addressed to Principal Dawson, dated Albany, October, 1862. Canadian Nat. and Jour. of Sci., new series, vol. 7, p. 377.

[3] Ibid., p. 380.

[4] Ibid., p. 381.

[5] See also "James Hall. Remarks on absence of Catskill group in New York." Albany Inst. Trans., vol. 4, 1863, pp. 307, 308.

Winchell, Alexander, on the identification of the Catskill Red Sandstone group with the Chemung (in a letter to J. D. Dana). Am. Jour. Sci., vol. 35, 1863, pp. 61, 62.

[6] Am. Jour. *Sci., vol. 34, p. 418.*

doubts of the Devonian character of the Old Red sandstone of New York when he had previously announced his conviction of the equivalency of the Marshall and Chemung groups, and of their common Carboniferous character. Since that time the confirmation of his doubts led Winchell to include within the Marshall (Chemung) group the Old Red sandstone of New York.

In his researches among the rocks of this age, the writer found an almost universal generic identification, establishing fully the equivalency of the Chemung, Marshall, Ohio, Rockford, Burlington, and Chouteau strata. He gives as evidence that these localities are all of Carboniferous age: "First, the fact that of the 135 species now known from the yellow sandstones of Burlington no less than 40 ascend into the base of the Burlington limestone, while 2 rise to the upper portion of it, and 1 recurs in the Coal Measures; second, the fact that of the known species of this horizon, at least 9 occur in the Coal Measures, or upper part of the Carboniferous limestone; while third, multitudes of species are clearly the local representatives of European and American Carboniferous types." Mr. Hall's declaration in the Canadian Naturalist "that large areas of the rocks of New York hitherto regarded as Chemung, do really fall within the limits of the Hamilton group," is said to account for the Devonian aspect of *some portions* of the Chemung fauna, as heretofore understood, and, Winchell adds, "tends to confirm a broad generalization, and complete the adjustment of American to European Paleozoic formations."[1]

Mr. James Hall[2] in 1870 announced that he had previously regarded the so-called "Montrose sandstone" (of Pennsylvania) and "Oneonta sandstone" of Vanuxem as lying above the Chemung rocks. The same views were held by Mr. Mather, who made the Montrose and Oneonta series equivalent to the upper part of the Catskill rocks. Further examination proved this conception of their relations to be erroneous and brought out the following parallelism of the groups in the eastern and western parts of the State:

Old Red sandstone of Tioga, etc.:	Catskill Mountain sandstone:
Chemung group.	Chemung group.
Portage group.	Oneonta group.
Hamilton group.	Hamilton group.

The Oneonta sandstone does not occur in the central part of the State, and its western extension has not been traced beyond Chenango County.

In 1875 Mr. Hall[3] again referred to the age of the Catskill formation.

In 1870 it was the prevalent opinion that, contrary to the author's statements, the Old Red sandstone did not exist in New York State.

---

[1] Regarding the development of Winchell's views on the correlations here announced, see the chapter on the Waverly Problem.

[2] Hall, James: On the relations of the Oneonta Sandstone and Montrose Sandstone of Vanuxem with the Hamilton and Chemung groups. Am. Nat., vol. 4, 1870, pp. 563-565.

[3] On the geology of the southern counties of New York and adjacent parts of Pennsylvania; *especially with reference to* the age and structure of the Catskill Mountain Range. Am. Assoc., Proc., vol. *24, pt. 2, pp. 80-84; Am. Jour.* Sci., 3d ser., vol. 12, 1876, pp. 300-304.

Further examination proved its existence, as well as the occurrence of higher formations. From these additional facts a map was constructed, colored to represent the different formations. The Catskills consist of a series of nearly parallel synclinals and anticlinals, with a southwest and northeast strike, running from the base of the Catskill range "to the western limit" of the red rocks in Chenango County. This continues to the western part of the State, but before reaching the boundary of western New York and Pennsylvania, it probably thins out entirely. In the southern part of New York State the synclinals show traces of the Coal Measures, while others are cut down to the Chemung.

The author states the difficulties that have arisen in determining the relation of the Chemung and typical Catskill. In some localities the Chemung fauna runs above its apparent horizon, and even mingles with Carboniferous forms. This fact is especially important when we attempt to determine the limit between the Devonian and Carboniferous formations. In the section exhibited which runs across the Catskill range from Schenevus to Glasco, the Portage and Chemung rocks have a thickness of over 2,000 feet, the Red Rocks of the Catskill about 3,000 feet, and the Vespertine beds about 800 feet.

He stated in 1880[1] that he found long ago that the Catskill Mountains of New York consist of Devonian rocks of Chemung and Catskill epochs, resting unconformably on Silurian rocks. Mr. Arnold Guyot in his observations found that the highest points of this region were on Slide Mountain, 4,205 feet, and the Panther, 3,828 feet above tide level. "As to structure, the beds show weak plications whose axes are parallel with those of the Alleghany system, but the mountain ranges were at right angles to the system, or from northwest to southeast." This anomaly is explained by erosion. "The general level descends westward."

The work of the Second Pennsylvania Survey had been conducted, up to 1880, or up to the time of preparing the reports published in 1880, on the plan that correlations could best be made by lithologic and stratigraphic means. Frequently one meets with expressions of lack of confidence in the evidence offered by the fossils.

In the correlation of the Coal Measures and as far down as the Catskill the fossils were not discovered frequently enough to serve as satisfactory means of correlation. In this case lithologic character, thickness, and stratigraphic order were the data which by aid of actual altitude of the strata in individual sections enabled the geologist to trace dominant formations from one township to another and from county to county. But as the work progressed, different geologists having charge of groups of two or three counties, the correlations at the edges of contiguous counties were constantly presenting disagreements.

The formations, where fossils were not present stubbornly to resist

[1] Hall, James: The geology and topography of the Catskill Mountains. Am. Nat., vol. 14, 1880, pp. 612–613. ½ p.

false conclusions, could be adjusted by compromise or by readjustment of nomenclature. In the case of fossiliferous zones the real difficulties became more apparent as the final adjustments were attempted.

Mr. Stevenson,[1] in 1878, said that the Upper Devonian rocks of southwest Pennsylvania, underlying the Vespertine or Pocono sandstone, are well exposed in the gaps of the Conemaugh River through Laurel and Chestnut Ridges. He gave a general section of these rocks as observed in the gaps, as follows:

	Feet.
1. Shales and thin gray sandstones	80
2. White to reddish-gray sandstones with some shale	70
3. Reddish-gray micaceous sandstones with red to gray and olive shales	150
4. Red to gray shaly sandstones with variegated clays and shales	200
	500

After a description of the rocks, and a discussion of their relations, he concluded by saying, that, "as the lithological characters of these rocks are much like those of the Chemung, and their fossils, both animal and vegetable, are unquestionably of Chemung age, the rocks themselves must be Chemung, probably representing the Lower Chemung;" and that "the great Catskill group has so far thinned out that it is represented only by its upper or gray member, the Vespertine of Pennsylvania."

The Pennsylvania reports published in 1880 gave little indication of the true nature of the errors of correlation of the Upper Devonian. In the Report of Progress G7,[2] the imperfection of the theory of "persistent parallelism of strata" became evident. The author classified the deposits examined as follows:

Pottsville Conglomerate, with 8 feet of slate and sandstone below it in a section at Susquehanna Gap.

Mauch Chunk Shale, No. XI, 150 feet.

Pocono group, No. X, 353 feet.

The Pocono-Catskill group, 400 feet thick near Loretto.

Catskill, No. IX, varying in thickness from 1,800 to 4,500 feet. The base of the Catskill is fixed as the lowest horizon at which the scales, teeth, and bones of *Holoptychius* occur.

The Catskill-Chemung group, section between Rupert and Catawissa, 1,077 feet. The base of this group was the lowest red bed.

Chemung, near Rupert, 2,443 feet thick.

Hamilton, at Little Fishing Creek, made up as follows:

	Feet.
Genesee slate	275
Tully limestone	50
Hamilton	400
Marcellus shale	410

This is called the "Northern type."

[1] Stevenson, J. J.: The Upper Devonian rocks of southwest Pennsylvania. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 423–430.

[2] *The geology of* the Susquehanna River region in the six counties of Wyoming, Lackawanna, Luzerne, *Columbia, Montour,* and Northumberland, by I. C. White, 1883.

The section below Selin's Grove is as follows:

	Feet.
Genesee slate	264
Hamilton group	2,022
Marcellus slate	300
Selin's Grove lower limestone	65
Selin's Grove shale	140
	505

This is the "Middle type."

The third or "Southern type" is exhibited at a railroad cut two miles below Georgetown.

	Feet.
Concealed	400
Selin's Grove upper sandstone	300
Selin's Grove shales	325
Selin's Grove lower sandstone	100 to 50
Marcellus?	25
Selin's Grove lower limestone	75
Gray shales	50

Oriskany sandstone. VII, placed in the Silurian by Mr. White, varying from 40 to 0 in thickness.

In the Campbell's Ledge black slate, immediately below the Pottsville Conglomerate, sixty-three species of plants and six fossil insects were obtained, a few of them suggesting "Subcarboniferous types," but the great majority were of the coal flora, known only from the Pottsville Conglomerate.[1]

High up in the rocks called Catskill, fossils of Chemung species were reported, as *Spirifera disjuncta* and *S. mesostrialis*.[2] This was some three hundred feet above *Holoptychius* remains.

Several species regarded as of characteristic Chemung age in New York were reported from several horizons in the Chemung-Catskill group. These, too, are well above red shales which had been regarded as at least as high as Catskill formations. In the Chemung, typical Chemung species were reported, but in combinations not precisely those commonly seen in the typical New York sections. The "Tully" was not recognized by its fauna, but on account of resemblance lithologically to the Tully limestone of New York.[3] The "Hamilton" is identified by typical Hamilton species. Thus is the "Oriskany" also distinguished. The identification of species is credited to Prof. E. W. Claypole.

The report called out sharp criticism, first in the letter of transmission by the State geologist who wrote:

> The paleontology of this report requires the closest consideration, and presents some difficulties of considerable magnitude, I have, therefore, submitted the proof sheets to our highest authority, Prof. James Hall, of Albany.[4] * * *

Prof. Hall objected to considering the *Holoptychius* bed as the base of the Catskill, because of the occurrence of Chemung species higher up.

[1] Rep. of Prog. G⁷, p. 39. [2] Ibid., p. 57. [3] Ibid., p. 76. [4] Ibid., p. XIX.

To "the topsyturvy appearance of the three species of *Spirifera* which outside of Pennsylvania have been found (1) never in any but Chemung rocks; (2) confined each to its own horizon; and (3) always in a fixed order from above downwards;"[1] and also to the high reported range of several species. The objections were so pointed that the State geologist, J. P. Lesley, closed his letter with the statement that "the startling fossil species of this report will therefore be regarded by the paleontological reader as only *provisionally verified*," etc.[2]

Two things about the report were out of the ordinary and expected line of opinion. The author, though partly recognizing the lithology as worthy of consideration, based his classification of these "subconglomerate" rocks on the evidence of the fossils and secondly he classified the rocks according to the evidence and not according to the standards as they existed in New York State. He was forced to recognize two "transition" groups in order to suit both kinds of evidence. This satisfied neither the lithologic nor the paleontologic schools of geologists.

The identification of fossils may not have been accurate in all cases, but the result of later studies has clearly shown that the real difficulty was not in the identification but in interpretations which were brought out by the facts. The minute and exhaustive field work of the second Pennsylvania survey had shown beyond the possibility of contradiction that geologic formations vary within wide limits in their lithologic character and in their thickness, and constantly, so that sections a few miles apart may present very little in common, although known to be stratigraphically correlative with each other. This had led to the full adoption of the idea that the parallelism of strata must be made by actual tracing of the strata from place to place, and that identification by lithologic likeness was impracticable over any considerable interval of space. Paleontologists, however, still clung to the theory of the strict uniformity of sequence in faunas.

The "canonical" opinion of the "highest authorities" in paleontology was that the order of sequence in species of fossils, established by the facts in one well authenticated section of deposits, furnished a standard that could be implicitly relied upon in the correlation of other sections. When it was reported that this established order was not preserved, doubt was naturally cast upon the identification of the fossils.

The Pennsylvania geologists did not seem to be aware of the importance of the facts, but they were correct and the error lay in the theory of the paleontologists.

Mr. Claypole,[3] in defense of his statements embodied in the Pennsylvania report, and criticised by Mr. Hall in the preface of the same volume, quoted from an article of Mr. Williams's, in which are recorded observations confirming his statements in Report G[7].

[1] *Rept. of Prog. G7*, p. xx. [2] Ibid., p. xxvi.

[3] *Claypole, E. W.: On the vertical range of certain fossil species in Pennsylvania and New York. Am. Naturalist, vol. 19, pp. 644-654.*

The principle underlying the new interpretation of this problem was suggested several years earlier in a paper read before the American Association in 1881.[1]

In this paper announcement was made of the discovery of a distinctly Hamilton fauna, all the species of which had been heretofore considered as strictly Hamilton species, in arenaceous shales several hundred feet above the Genesee shales, at Ithaca, New York. It is separated from the typical Hamilton fauna by four distinct faunas; those of the Tully limestone, the Genesee shale, the *Spirifera lævis* fauna, called Portage in the State reports, and a fauna described in this paper from shales overlying the last, called "Ithaca shales," resembling the Genesee shale fauna, but evidently a later stage of it. This black shale was regarded by the author as "a single continuous fauna." He says:

> Its appearance in the rocks of central New York in three separate zones, called the Marcellus shales, the Genesee slate, and the Ithaca shales is regarded as evidence of interrupted incursion eastward of the conditions which were continuous over some portions of the interior of the Devonian intercontinental sea, where the three New York zones were represented by one continuous series of Black shales.
>
> The hypothesis is also advanced that (*a*) the Hamilton and Chemung faunas were probably coexistent with this Black-shale fauna; and (*b*) were respectively the northern and southern faunas of a western coast line of the open ocean on the eastward of this continent; and (*c*) the appearance of the Chemung fauna, displacing the Hamilton faunas, in the latitude of New York and Pennsylvania, was the resultant of some grand changes in the relations of the ocean and continental borders, by which tropical conditions of the ocean were advanced northward, occasioning the shifting of the Hamilton faunas toward the North pole; so that (we may suppose) at the time when the Chemung fauna was dominant over the northeastern United States, rocks being deposited in the arctic latitudes received a Hamilton fauna; and (*d*) finally, these changes were gradual, the shifting of the faunas northward beginning as early as the beginning of the Portage epoch, and continuing far into, and perhaps after the close of the Chemung epoch, with some oscillation of the conditions, causing traces of the Hamilton to recur at the base, and possibly a second time higher up in the midst of Chemung rocks and faunas.

The fundamental idea inspiring the paper was an application of conditions of modern biology to the interpretation of the fossil faunas. As in the present seas many faunas are known to coexist in the same ocean basin, their particular constitution and characteristics being determined in great measure by differences of environment, bathymetrical conditions, temperature, purity of water, etc., so in the past, it is supposed, similar differences in the faunas will be found to mark deposits which were made at the same time, but under different conditions. And in the second place since oscillations are known to have occurred and currents are supposed to have existed in the ancient as in the modern oceans, according to the theory it is reasonable to expect a more or less constant change of the conditions of environment at any particular geographical position, and consequently a shifting backward and forward over it of the faunas during the accumulation of the sedi-

[1] The Recurrence of Faunas in the Devonian Rocks of New York, by H. S. Williams. Proc. Am. Ass. Adv. Sci., vol. 30, pp. 186-191.

ments. With this as a working hypothesis the paper on "Recurrence of faunas" was the announcement of the first confirmatory evidence actually seen. Barrande's theory of "Colonies" considered the laws concerned as exceptional; the theory of the recurrence of faunas was set forth as the formulation of a general law.

Investigations in the same line were extended by the author westward from the meridian of Cayuga Lake, New York State, across the State, northwestern Pennsylvania, and the eastern part of Ohio. The rocks studied were of Devonian and Lower Carboniferous age, and the problems were the same over which the Pennsylvania geologists were struggling.

In 1883, Mr. Claypole[1] reported that the Catskill group of New York had hitherto been considered as non-fossiliferous, and as separating the characteristic Devonian and Carboniferous faunas. Further examination, however, proved that these rocks contained a scattered fauna consisting of fish and plant remains. From a study of these deposits in central Pennsylvania, the author reached the following conclusions:

(1) That the lower portion of the Ponent Red sandstone and shale (Catskill) is less barren of organic remains than has been supposed. (2) That Holoptychius and Bothriolepis are not exclusively Catskill fauna, and (3) That the Ponent group differs from what it is generally understood to be, the contained fossils indicating that there are Chemung and also Carboniferous faunas included in rocks called Ponent.[2]

Mr. Claypole,[3] during the same year, communicated several other papers bearing more or less upon the general discussion.

In the same year (1883) in which Report G[7] of the second geological survey of Pennsylvania appeared, the manuscript of Bulletin 3 of the U. S. Geological Survey [4] was furnished, though not published till the following year.

The bulletin is a report upon the constitution, the order, and relative position of the fossil faunas in a continuous section of the rocks, from the Genesee shales through the Upper Devonian to the first appearance of a coal bed at the Barclay coal mines in southern Bradford County, Pennsylvania.

---

[1] Claypole, E. W.: On the occurence of fossiliferous strata in the Lower Ponent (Catskill) group of middle Pennsylvania. Am. Nat., vol. 17, 1883, pp. 274-282.

[2] Ibid., p. 282.

[3] Claypole, E. W.: Note on the occurrence of Holoptychius about 500 feet below the recognized top of the Chemung group, in Bradford County. Proc. Am. Phil. Soc., vol. 20, 1883, p. 531.

On a mass of Catskill rocks, supposed to exist on the north bank of Towanda Creek, near Franklin. Proc. Am. Phil. Soc., vol. 20, 1883, pp. 531 533, 535.

On two small patches of Catskill, represented near Leroy, on the map in report G, of the second geol. survey of Pennsylvania. Proc. Am. Phil. Soc., vol. 20, 1883, pp 533 534.

On the Kingsmill white sandstone. Am. Phil. Soc., Proc., vol. 20, 1883, pp. 666-677.

On the equivalent of the New York Portage, in Perry County, middle Pennsylvania. Am. Phil. Soc. Proc., vol. 21, 1883, pp. 250 255.

On a large crustacean from the Catskill group of Pennsylvania. Am. Ass. Proc., vol. 32, 1883, p. 265.

[4] On the fossil faunas of the Upper Devonian along the meridian of 76° 30', from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams.

A notice of the general results, embodied in the bulletin, appeared in Science, December 28, 1883. (*Comparative Paleontology of* the Devonian formations, Science, vol. 2, p. 836.)

The consecutive faunas were also examined particularly as to conditions of environment with which they were originally associated, as indicated by the lithologic character of the deposits. The scope of the work may be indicated by the following quotations:

The aggregation of species into faunas, the blending of one fauna with another, the rarity or abundance of particular species, variation in form or size or modification of specific characters, the extinction of old and the initiation of new forms—all these become the most delicate tests of change in the physical conditions, the record of which constitutes the geological history of the earth.

For the correct solution of this problem the laws of geographical distribution form as important an element as geological sequence. The attempt to apply such principles to the study of the Devonian and Subcarboniferous deposits is no simple task, but the very fact that their faunas offer so great variation and difference in their combinations makes this series particularly attractive for the purpose.[1]

* * * * * * *

These facts make it plain that over any particular area the faunas shifted back and forth with the advance of geological time. Hence I was led to the simple conception of a fauna as continuing on intact as long as the favorable conditions for its life continued, as shifting its habitat with the elevation or depression of the land, with the advance or retrocession of the coast line. In such shifting and change of conditions, one species after another may drop out and become extinct; others may suffer varietal modification, and, what is still more important, the sudden appearance of new forms may take place in the midst of the normal fauna—forms new to the locality only, or entirely new, so far as our knowledge of the fossils can tell us. Merely from the initiation of the new forms in the fauna we can gain no clew of its origin, but the study of its relations to allied forms of other faunas may enable us to decide whether it is a modification of some older form or the forerunner of a new type, marking a later geological stage.[2]

* * * * * * *

The following is a summary of the order and general relative position of the faunas from the Genesee slate to the Barclay coal, which my present knowledge leads me to believe is true for the meridian passing through Ithaca, New York, running southward.

(1) Genesee slate fauna,

(2) Portage group fauna, distributed through approximately 1,300 feet of strata, but interrupted by the intrusion of the Ithaca faunas and several sub-faunas.

(3) Chemung fauna, occupying at least 1,200 feet of strata, with perhaps two subfaunas, and driven out or destroyed by the presence of the conditions marked by the deposit of red and gray Catskill rocks.

Within the limits assigned to the Portage group in the western part of New York State, I believe should be included for this meridian all those deposits lying between the Genesee shale and the lowest yellow-brown shale and sandstones which carry the true Chemung group fauna.

This series, as a whole, may be described as arenaceous, dark-colored shales with the *Cardiola speciosa* fauna, toward the top running into wave-marked, tough, arenaceous deposits, almost totally barren, so far as known.

The passage between this series and the true Chemung is stratigraphically indistinct, but in a general way it may be recognized by the clearer separation of the argillaceous from the arenaceous deposits after passing the line, and the appearance of lighter-colored sandstones in the midst of softer argillaceous shales, in which iron nodules and iron stains become more conspicuous than below.

The shales of the Portage below are thinner and of more greenish tint, and its

[1] U. S. Geol. Surv., Bull. No. 3, p. 6. [2] Ibid., p. 8.

sandstones are darker in color and thin, tough, and wave-marked or flaggy. Paleontologically, however, the transition is more marked.

The upper part of the Portage appears to be utterly barren except in an occasional thin stratum of green shale, a *Cardiola speciosa*, or a small *Palæoneilo*, or *Leda* may appear.

As soon, however, as we reach the true Chemung rocks we meet large *Productella lachrymosa*, *Ambocœlias* and *Spirifers* of the Chemung types. * * *

To the author of this bulletin the facts reported by Mr. White in the Report of Progress G[7] were not startling, but what he was ready to expect from his studies in New York. He expressed his agreement thus:

In regard to the identification of these Upper Devonian faunas of Columbia County, Pennsylvania, in the association of species and the relative order of the sub-faunas, the record agrees in general with that of the series exposed along the same meridian farther north in New York State.[1]

The following year, 1884, the same author read a paper before the American Association on "Geographical and physical conditions as modifying fossil faunas."[2] In this paper application of the principles above described is made in the study of sections of the Devonian rocks east and west of those described in the Bulletin No. 3. By dissecting the faunas of each section and comparing them consecutively across the State, is it shown that there are changes in the composition of the faunas coordinate with changes in the deposits. Among other examples the occurrence of Castkill type of fossils with Catskill character of rocks in Chenango and Otsego Counties, New York, is reported entirely below genuine Chemung fossils, in the Oneonta formation.

In the discussion which followed, Mr. Hall, to whom the objectionable identifications of the Pennsylvania Report G[7] had previously been referred, again objected to the report that *Spirifera mesostrialis* and *S. disjuncta* were found together, on the ground that they represent different zones and should not occur together; also, he objected to the interpretation of strata as "Chemung-Catskill," claiming that these are two distinct formations with distinct faunas, and it was not reasonable to expect the two to be blended. At the same meeting, in a paper read by Mr. Hall, this opinion is further illustrated by his interpretation of a section in Warren County, Pennsylvania.[3] In the section described about 1,500 feet of Chemung rocks are reported with Chemung fossils, followed immediately, and without sign of unconformity, by Waverly sandstone rocks with Waverly fossils. Between the two is marked "*the place of the Catskill*," where, it is stated, "there is a hiatus which in eastern New York and Pennsylvania is marked by the presence of measures having a thickness of from 3,000 to 5,000 feet."

The interpretation of the facts is "that there has been a long interval of time between the final deposition of the barren Chemung shales and the fossiliferous Waverly sandstones, or that the deposition of the

[1] See "The Spirifers of the Upper Devonian," by H. S. Williams, Science, vol. 3, p. 374.

[2] Proc. Am. Assoc. Adv. Sci., vol. 33, p. 422, et. seq.

[3] *On the intimate* relations of the Chemung group and the Waverly sandstone in northwestern *Pennsylvania and southwestern* New York, by James Hall, Proc. Am. Assoc. Adv. Sci. vol. 33, p. 416.

estuary Catskill sediments has been going on simultaneously with the open sea deposits of the Waverly formation."[1]

The true objection to such terms as "Chemung-Catskill" and "Catskill-Pocono" did not come to light in this controversy. The names do not misrepresent the facts they were intended to represent, i. e., that in Pennsylvania there are formations which by their fossils indicate not only transition, but a blending of two distinct formations of New York, but it may be urged that these names do not clearly express the facts. The truth is that sedimentation did not change synchronously for even very limited areas, and to attempt by the use of nomenclature to make the division lines of the chronological scale precisely coincide for the sections of adjoining States will often unnaturally strain the facts.

In 1885 Report of Progress F^2 was published.[2] In this report the classification adopted in Mr. White's Report G^7 was more fully elaborated. Mr. Claypole's classification is as follows:

No. XI. Mauch Chunk red shale.
No. X. Pocono sandstone.
No. IX. Catskill formation, including—
Upper beds.
Dellville sandstone.
King's Mill shales.
King's Mill sandstone.
Fish beds.
No. VIII (*f*). Chemung group.
No. VIII (*e*). Portage group.
No. VIII (*d*). Genesee group.
No. VIII (*c*). Hamilton group, including—
Hamilton Upper shale, 200 to 300 feet.
Hamilton (Montebello) sandstone, 500 to 800 feet.
Hamilton Lower shale, 400 to 500 feet.
No. VIII (*b*). Marcellus limestone and black shale, including
Marcellus black shale, 100 feet.
Marcellus upper iron ore, 2 feet.
Marcellus limestone, 50 feet.
Marcellus lime shales, 50 feet.
Marcellus lower iron ore, 2 feet.
No. VIII (*a*). Upper Helderberg (Corniferous) group. (Absent.)
No. VII. Oriskany sandstone group.

The division line between the Chemung group and the Catskill is not clear. Occasional red beds occur below the line he sets, and Chemung fossils occur above the "Fish beds," which he regards as the base of the Catskill.[3]

In 1885 Williams read a paper on the classification of the Upper Devonian.[4]

---

[1] On the intimate relations of the Chemung group and the Waverly sandstone in northwestern Pennsylvania and southwestern New York, by James Hall, Proc. Am. Assoc. Adv. Sci., vol. 33, p. 418.

[2] Second Geol. Survey of Pennsylvania, Report of Progress F^2. A preliminary Report on the Palæontology of Perry County, describing the order and thickness of its formations and its folded and faulted tructure, by E. W. Claypole. Harrisburg. 1885.

[3] Ibid., pp. 72, 73.

[4] On the classification of the Upper Devonian, by Henry Shaler Williams, Am. Ass. Adv. Sci. Proc., vol. 34, 1885, pp. 222-234.

A number of sections across the same series of deposits, about 50 miles apart, are compared. The sections are called: I Cuyahoga, II Painesville, III Girard, IV Chautauqua, V Genesee, VI Canandaigua, VII Cayuga, VIII Tioughnioga, IX Chenango, X Unadilla, making a series reaching from Cleveland, Ohio, to the Unadilla Valley, Otsego County, New York.

The individual faunas were studied in their stratigraphic order in the various sections, and their relative positions in the sections were shown to exhibit a shifting back and forth of the faunas during the deposition of the sediments. The faunas were classified and the recurrent stages of each were given names from the dominant fossils, characterizing them as follows:[1]

A is the Hamilton fauna and its immediate successors.

The middle Devonian fauna (A) was traced above the horizon of the Genesee shale in the following successive stages:

A 1, the *Paracyclas lirata* stage.
A 2, the *Spirifera lævis* stage.
A 3, the *Strophodonta mucronata* stage.
A 4, the *Atrypa reticularis* stage.
A 5, the *Leiorhynchus globuliformis* stage.
A 6, the *Tropidoleptus carinatus* stage.
A 7, the *Spirifera mesostrialis* stage.
A^8+ is a second recurrence of the *Tropidoleptus* stage, found above the Chemung fauna and distinguished by the variety *Owegoensis* of *Spirifera marcyi*, a characteristic variety of the *granulifera* type of *Spiriferas*.
B is the black shale fauna, beginning in the typical or first stage of the Genesee shale.

In the fauna of the black shales:

B, the Genesee stage of *Lingula spatulata*.
B 1, the second *Lingula spatulata* stage, in Portage shales.
B 2, the *Lingula complanata* stage of the "Ithaca group."
B 3, *Lingula spatulata*, third variety, in the Cleveland shale.
B 4, *Lingula complanata*, second stage, in Chemung shales.
C is the fauna of the green shales of the typical Portage group.
C 1 is the Cephalopod stage, with *Goniatites* and large *Cardiadæ*.
C 2, the Lamellibranch stage, with *Cardiola speciosa*, etc.
C 3 is the Portage sandstone, generally barren.
D is the Chemung fauna associated with brown argillaceous shales, flags, or calcareous sandstones.

The faunas of the brown shales and sandstones of the Chemung deposits were classified into the following stages:

D 1, the stage of *Orthis tioga*.
D 2, the stage of *Strophodonta cayuta*.
D 3, the stage of *Athyris angelica*.
D 4, the stage of *Rhynchonella contracta*.
D 5, the stage of *Spirifera alta*.

All of these stages, except the first (D 1) are characterized by the presence of some variety of *Spirifera disjuncta*) = *Sp. Vernuili*).

E is the fauna of the flat pebble conglomerate.
F is the fauna and flora of the Catskill grays and reds.

In the Catskill rocks the fossils are very rare, but there are two stages (F 1) of the

[1] *On the classification of the Upper Devonian*, by Henry Shaler Williams, Am. Ass. Adv. Sci. Proc., *vol. 34, 1885, pp. 225-227.*

Oneonta reds and grays and (F 2) of the typical Catskill. So far as fossils have been found there is difficulty in defining them.

It is probable that *Holoptychius* and several allied fish, Conrad's *Cypricardia angusta* and several plants, are found in both alike, but further investigation will be necessary to establish any clearly distinctive characters in the fossils.

The Waverly fauna G appears to be distinguished into three stages in other parts of Ohio. But in the region comprised in these sections the stages are recognized more by their lithologic than by their paleontologic characters. The general fauna may be called the *Syringothyris* fauna,

With G 1, the Bedford shale stage,
With G 2, the Berea grit and sandstone,
With G 3, the Cuyahoga shale and sandstone.
H is the conglomerate (Olean and equivalent).
J is the Barclay coal beds.

From these studies the following principles of correlation were deduced:[1]

First. The complications arising from both geological and geographical modifications of fossil faunas are so great that the attempt to determine horizons by single or by roughly identified fossils will certainly lead to erroneous results.

Second. In classifying deposits in geologic surveys, it is of the greatest importance that the actual altitude and the geographic position of rock strata should be precisely defined, as well as the lithologic character of the strata themselves. And for this purpose some systematic and uniform nomenclature for the various kinds of rocks should be made and adopted by all geologists in the country.

Third. The fact that species composing the faunas and the total faunas themselves are subject to constant modification, both geographical in the same horizon and geological in the same area, is an element that paleontologists can not safely ignore. These modifications, though they may be slight, can be easily recognized in the passage of 50 miles.

Fourth. The actual order of faunas met with in a vertical section is not necessarily expressive of biologic sequence, but signifies the sequence of the occupants of that particular area.

The change in the species from one stratum to the next may express the shifting for miles of the actual inhabitants, and if the change, within a few feet of strata, is to an entirely distinct group of species, the evidence should be taken as pointing to a considerable shifting of condition of the bottom. If in such case each fauna is kept distinct, the means of tracing the geographical distribution and modification are at hand. If mingled, then the collection, though made at the same locality, will only confuse. Two such faunas meet at Owego, Tioga County, in distinct strata, but in rocks which are of similar lithologic character. One is a remnant of a prevailing western fauna, the other is an eastern and late stage of a new fauna.

Fifth. The classification of the rocks may receive local geographic names; the classification of the biologic series should receive names derived from the names of species; ages defined by families, periods by genera, and epochs by species, or something of that kind, and these periods or ages will always adjust themselves to future discoveries.

Regarding the classification of the particular formations the following conclusions were reached, viz:

(1) The Devonian black shales occur in the strata from the Genesee shales upward, alternating with the normal deposits of the Portage and Cleveland shales and sandstones, and possibly higher, with modifications of the faunas, but run out at the eastern extremity of the area.

[1] On the classification of the Upper Devonian, by Henry Shaler Williams, Am. Ass. Adv. Sci. Proc., vol. 34, 1885, pp. 232.

(2) The Portage rocks and faunas are local, the characteristics of each being unrecognizable east of the Cayuga section.

(3) The typical Portage formations of the Genesee section have quite a different set of species from the rocks occupying the same interval in the Cayuga section, while farther east the same interval is filled by rocks like the Catskill, called the Oneonta sandstones, etc.

(4) The "Ithaca group" contains a *modified* Hamilton fauna, which differs from the Chemung fauna in the absence of some of its most characteristic species.

(5) The modified stages of the Hamilton fauna appearing above the Genesee shale are confined to sections east of the Canandaigua meridian.

(6) The Catskill deposits of Chenango and Otsego Counties are intrinsically not distinguishable from those of the higher stage called Catskill, but appear at a lower position, stratigraphically, in the interval occupied by the "Ithaca group" of the Cayuga section, and by the middle part of the Portage group of the Genesee section; but paleontologically they are immediately preceded by stages of the same general fauna.

(7) The dominant and most characteristic species of the Chemung fauna appear stratigraphically earliest in the more western sections (D 4 of Girard and Chautauqua). This stage of the fauna appears in the upper part of the Chemung group in the eastern sections; and in the extreme part of the area this stage of the fauna is all that appears, and it is there represented by only a few specimens in the very upper strata just before the final incursion of the Catskill deposits.[1]

[1] Op. cit., p. 234.

CHAPTER VII.

THE LOWER CARBONIFEROUS OR MISSISSIPPIAN SERIES: THE DEVELOPMENT OF THE NOMENCLATURE, AND CLASSIFICATION OF THE LOWER CARBONIFEROUS FORMATIONS OF THE MISSISSIPPIAN PROVINCE.

The presence of the Carboniferous system in America was early recognized by finding coal beds containing plants similar to those of the Coal Measures of Europe; but the determination of the lower and upper limits and the classification of the Carboniferous formations were matters of gradual development.

In the northern and central portions of the Appalachian province the interval between the marine Devonian formations and the Coal Measures is mainly filled by arenaceous deposits with few distinguishing fossils, and here the more interesting correlation problems were concerning the termination of the Devonian.

In the Mississippian province the sedimentation introducing the Carboniferous was strikingly different. A considerable series of limestones and calcareous shales, and a few sandstones intervene between the termination of the Silurian and the base of the coal-bearing strata above. These rocks contain rich and varied fossil faunas, and their correlation and classification constitute one of the most important chapters in American geology. Rocks containing Devonian faunas are found at the base of the series in some parts of the province, but in other sections they are missing. The formations resting upon the Devonian where these occur, and in other places upon the Silurian, are characterized by fossils of Carboniferous age, and have heretofore gone under the names "Mountain limestone," "Carboniferous limestone," "Subcarboniferous," and "Lower Carboniferous." No one of these names is satisfactory, and as these formations are bound together by a common general fauna and constitute a conspicuous feature in the geology of this region, it is proposed to call them the *Mississippian series*. This series may be defined stratigraphically as that series of rocks, prevailingly calcareous, which occupies the interval between the Devonian system and the Coal Measures, and is typically developed in the States forming the upper part of the valley of the Mississippi River, viz, Missouri, Illinois, and Iowa. The name is a slight modification in form and usage of a name proposed by Alexander Winchell in 1870.[1]

[1] The Marshall group, etc., Am. Phil. Soc., Proc., vol. 11, p. 79.

He proposed "the use of the name" "Mississippi limestone series or Mississippi group" "as a geographical designation for the Carboniferous limestones of the United States which are so largely developed in the valley of the Mississippi River."

At the time this was written the Chouteau group of Broadhead was correlated with the Chemung group of the New York geologists, and one of the important results of Winchell's paper was the demonstration that the Chouteau group of Missouri, the Kinderhook group of Illinois, the Waverly group of Ohio, and the Marshall group of Michigan were different types of a single formation of more recent age than the Chemung group of New York.

As the Carboniferous age of the Chouteau and Kinderhook faunas is fully established, it appears entirely appropriate to extend the limits of the Mississippian series so as to include all the formations containing Carboniferous faunas from the top of the Devonian to the base of the Coal Measuses. I have already proposed the use of the name in this sense in recent reports to the State geologists of Arkansas and Missouri.

As the nature of sedimentation is greatly determined by the geographical relations of ocean to shore lines, a brief description of the geographical conditions of the region during the upper Paleozoic is here appended.

At the opening of the Devonian period the Archean continental nucleus of the Northeast had been increased by a considerable border of Silurian formations. The borders of this land mass roughly defined extended from near the mouth of the Mackenzie River southeastward to Lake Winnipeg, and as the line approached Lake Superior it was diverted westward, to what extent we do not know, as the more recent deposits cover the record. The shore line appears again running across the northeast corner of Iowa, thence eastward across Illinois, and there suddenly bends northward, forming a great bay, taking in the peninsular part of Michigan; thence eastward across Ontario, northern New York, and around the Catskill Mountains into New Jersey; thence with some interruptions southwestward, forming an eastern shore for the Appalachian basin.

The Cincinnati uplift was probably an island for part of the Devonian period, and the Ozark uplift of southeastern Missouri formed another large island, which probably remained above water throughout the Carboniferous. Other islands may have furnished shores of erosion farther to the south and west. Thus from the beginning of the Devonian till the time of the general continental elevation which initiated the Coal Measures, the central part of the United States was a vast ocean basin. The sedimentation about the margins of this basin was prevailingly arenaceous and argillaceous, the formations are more varied, and it is in these margins that we find the best development of the Devonian system, both stratigraphically and faunally considered. As we approach the central portion of the basin the sedimentation is prevail-

ingly calcareous; and the strata representing the Devonian system become reduced in amount, and less varied in composition, and contain a limited fauna; and, finally, in Alabama, Tennessee, Arkansas, and southern Missouri, a black shale only a few feet in thickness, with Lingulas and rarely other fossils, is all that represents the complex stratigraphy and paleontology of the Devonian of New York. The "Black shale" has consequently assumed an important role in the correlations of the Mississippian series.

The upper termination of the series is marked by the more or less rapid change from calcareous to coarse arenaceous deposits, indicative of elevation and shore line sedimentation.

In the Appalachian province, Rogers's "Seral Conglomerate" has been adopted as the base of the Pennsylvania series of Coal Measures, but in the Mississippian province, although the coal beds are preceded by a greater or less thickness of arenaceous sediments, the delimitation between the Mississippian and the Coal Measures, as we shall see, is not yet drawn with any great degree of precision.

Thomas Nuttall, in the year 1821, in the article referred to on p. 25, made the first allusion discovered in our literature to the limestone rocks of the Mississippi Valley as a formation possessing common characteristics. These limestones he rightly interpreted by recognizing in them the fossils of Martin's Petrifacta Derbiensis. It is not probable that he, any more than many geologists who immediately followed him, recognized the distinction between the true Carboniferous limestones and others of Silurian and of Devonian age. The fact that the limestones which he described as forming the calcareous platform of the Mississippi are conspicuously of Lower Carboniferous age, and that for years they went under the names "Mountain limestone," "Carboniferous limestone," and "Cliff limestone," is sufficient reason for giving special consideration to these Mississippi Carboniferous limestones.

It was D. D. Owen, however, who devoted careful study to the Mississipian series and first described and elaborated the details and proposed a distinct nomenclature and classification. His earlier views on the subject are found in the reports of the geological survey of Indiana. The first and second annual reports were published in 1839.[1]

In the first report Owen gave the general outlines of the system then in use in Europe as expressed in De la Bèche's Manual, and constructed a section representing his interpretation of the rocks "along a line from Terre Haute running southeasterly toward that part of the Alleghany range which divides Tennessee from North Carolina," thus:

Bituminous coal formation.
Mountain limestone.
Grauwacke.
Crystalline and inferior stratified rocks.

[1] Report of a Geological Reconnoissance of the State of Indiana made in the year 1837 in conformity to an order of the legislature. By David Dale Owen, M. D., geologist of the State, pp. 34, 1839.
Second Report of a Geological Survey of the State of Indiana made in the year 1838. By David Dale Owen, 1839.

In the course of the survey a line was run along the Ohio River, and the succession there is interpreted as follows:

Coal formation.	Seams of coal associated with beds of sandstone, shale, clay, and limestone.
Subcarboniferous group.....	1. Oolitic limestone. 2. Encrinital strata, Siliceo-calcareous series with occasional beds of clay. 3. Black bituminous aluminous slate. 4. Fossiliferous and inferior strata of the Subcarboniferous group, consisting of (1) Fossiliferous bed of Ohio Falls. (2) Water-lime and variegated strata. (3) Sand or burr stone. (4) Bluish or brownish limestone.

On page 25 the rocks of the State are classified into three formations:

1. A bituminous coal formation.
2. A limestone formation (similar to the Mountain limestone of European geologists).
3. A diluvium.

In this report the Carboniferous group is restricted to the coal-bearing rocks, or what is now called the Coal Measures.

All the fossiliferous rocks below the Coal Measures were called "Subcarboniferous." The author said:

To this group may with propriety be applied the name Subcarboniferous, as indicating its position immediately beneath the coal, or Carboniferous group of Indiana; [and in a foot note], "The fossils generally coincide closely with those of the Carboniferous or Mountain limestone of Europe; but as no perfect seams of coal have ever yet been observed alternating with these deposits in this country, and as most of its fossils differ decidedly from those of the coal formation, it would seem to preclude the possibility of including it, here at least, as some European geologists do their Mountain limestone, in the Carboniferous group. * * * I prefer designating it by the term "Subcarboniferous," which merely indicates its position beneath the Carboniferous group without involving any theory.[1]

In the second report, published the same year, Owen briefly reported details for various counties of the State. The "Encrinital strata of Harrison County" are said to "correspond to the 'incrinital' of Dr. Troost" of the "well known iron region of Tennessee." The rocks below the fossiliferous strata of the Falls of Ohio were correlated with the "Cliff strata" of Dr. Locke, of Ohio, and "most of the rapids and falls in the State are produced by these cliff rocks."[2] And in the discussion of the rocks near Lockport and near Delphi, the author remarks:

The whole of the rock formation which I have just been describing I consider as belonging to the strata inferior to the black bituminous aluminous slate, including part, if not the whole, of the Cliff strata.

In the latter part of the report a comparison is made between the geological formations of Indiana and those of Ohio.

---

[1] Report of a Geological Reconnoissance of the State of Indiana made in the year 1837 in conformity to an order of the legislature. By David Dale Owen, M. D., geologist of the State, 1839, pp. 12, 13.

[2] Second Report of a Geological Survey of the State of Indiana made in the year 1838. By David Dale Owen, 1839, p. 17.

The bituminous coal formation of Indiana is correlated with the coal fields of lower Missouri, northwestern Kentucky, and Ohio, thus:[1]

INDIANA.	OHIO.
Oolitic limestone (of Troost)	= "Conglomerate" of Locke.
The soft freestone of the Knobs.....	= Waverly sandstone rock, which caps the hills bordering on the Scioto Valley, Ohio.
The black slate at the base of the Knobs	= The shale stratum in "the base of the hills capped with sandstone, bordering on the Scioto Valley."
Arenaceous and argillaceous limestone, forming falls and cliffs in Madison County, on the Ohio River, and on the Upper Wabash, etc.	= Cliff rocks.
Blue fossiliferous limestone.....	= Blue fossiliferous limestone.

The whole of the series above described, from the bottom of the coal formation downward, that is, the Subcarboniferous group, has received the name of "Galeniferous limestone" from some geologists, because it has yielded in a few of the Western States an abundant supply of galena.

The next contribution Owen made was his report on the mineral lands of the United States, which first appeared as a Presidential message to the House of Representatives in 1840.[2]

As we glance over the introduction to this document we find that Owen regarded all the stratified rocks, from the Coal Measures downward, including the "Blue Fossiliferous limestone" (Cincinnati limestone), as belonging to the Mountain limestone of the English geologists. For the States of Ohio, Indiana, Kentucky, and Tennessee this Mountain limestone was represented by him under the following subdivisions:[3]

Pentremital limestone, light-colored limestone, sometimes oolitic.
Fine-grained sandstone in Knobs.
Black bituminous shale.
Thick beds of yellowish limestone, Cliff limestone of the West.
Blue fossiliferous shell limestone in thin beds with marlite.

Of these the Cliff limestone was dominant in Iowa and Wisconsin, and the other members were absent or greatly diminished, as in the case of the Blue limestone, so that in Iowa and Wisconsin the following subdivisions were observed:[4]

Pentremital limestone.
Cliff limestone.
Blue limestone.

---

[1] Geol. Surv. Ind., 2d Report, pp. 39–45.

[2] "Mineral Lands of the United States. Message from the President of the United States in reply to a resolution of the House of Representatives, February 6, 1840. House of Representatives, Executive Document No. 239, Twenty-sixth Congress, first session."

Report on a geological exploration of part of Iowa, Wisconsin, and Illinois, made under instructions from the Secretary of the Treasury of the United States, in the autumn of the year 1839, by D. D. Owen, M. D., principal agent to explore the mineral lands of the United States, pp. 9–160.

[3] Ibid., diagram 4, op. p. 14.

[4] Ibid., diagram 5.

The sandstones below the blue limestone were regarded as equivalents of the Old Red sandstone.

Another table exhibits the following classification of the rocks of Iowa and Wisconsin:

Coal formation	Coal, shale, grit, and slaty clays with ironstone.
Carboniferous or Mountain limestone formation	Cliff limestone.
	Blue fossiliferous limestone.
Old Red formation(?)	Alternations of red and white sandstone and Magnesian limestone.
	Red sandstone.(?)

John Locke, in a report accompanying Owen's report, stated that he had used the term "Cliff limestone" in the Ohio report (1858), adopting it as a provisional name "from the inhabitants on the Miami above Dayton, Ohio." He gave a list of synonyms:[1]

Galeniferous limestone, Featherstonhaugh.
Cornutiferous limestone, Eaton.
Magnesian limestone, Keating and Shepherd.
Mountain limestone, Ohio Reports.
Cliff limestone.

The name "Cliff limestone" is adopted in this paper as a synonymous term for the "Scar limestone" of Phillips's Geology as it appeared in the seventh edition of the Encyclopedia Britannica.

This report was printed on the 4th of June, 1840, without the accompanying charts, sections, and illustrations, and transmitted to the House of Representatives. It was revised, and the public edition was ordered by the Senate to be printed June 1, 1844. The executive document of the House (No. 239) appears to be the first edition unrevised, and there were ordered printed (February 25, 1843) 5,000 extra copies for the use of the House.

Some important revisions first appearing in the Senate document are as follows:

First, a modification of the classification, expressed in a table giving a comparative view of the correspondence between the New York and English surveys, modified from Hall's table of formations in the Final Report on the Fourth District of New York, published in 1843. In the table of the 1844 edition the "Blue limestone" is the equivalent of the Trenton limestone, Utica slate, and Hudson River groups of the New York system. The "Cliff limestone" was recognized in part as the equivalent of the Clinton group, Niagara group, the Onondaga, and the Corniferous limestones of the New York system. The "Black slate" of Ohio and Indiana was the equivalent of the Marcellus shale of New York, and the Waverly sandstone and "fine-grained sandstone of the Knobs" were considered as the equivalents of the Portage and Che-

[1] "Mineral Lands of the United States. Message from the President of the United States in reply to a resolution of the House of Representatives, February 6, 1840. House of Representatives, Ex. Doc. No. 239, Twenty-sixth Congress, first session."

Report on a geological exploration of part of Iowa, Wisconsin, and Illinois, made under instructions *from the Secretary of the Treasury* of the United States, in the autumn of the year 1839, by *D. D. Owen, M. D., principal agent* to explore the mineral lands of the United States, pp. 116, 117.

mung groups. Owen subsequently changed these last two correlations.

In a footnote[1] Owen mentioned Hall's substitution of the term Niagara for "Cliff limestone," and on page 28 of the same document he stated:

A review of the fossils of the region under consideration proves, however, that the Cliff formation of Iowa and Wisconsin is, in point of fact, the American equivalent of the Upper and perhaps of part of the Lower Silurian formations of Murchison.[2]

Owen introduced another distinction which is of great importance, but would scarcely be noticed were we not watching for it. In the House edition of the report, the table giving the rocks of Iowa and Wisconsin has "Carboniferous or Mountain limestone" for the rocks below the Coal Measures,[3] and the revised edition[4] has "Subcarboniferous limestone or Protozoic rocks" in its place, and on page 32 is added a clause describing the "Carboniferous limestone of Iowa." Under this heading the author included the reddish limestones of Rockingham, Iowa,[5] and some dark encrinital layers near Stevenson, Illinois.

The "white limestones" of the same part of the State the author reported as contemporaneous with the "shell beds" on the Falls of the Ohio, and as representing by their fossils the Onondaga, Corniferous, Marcellus, and Hamilton groups of New York.

The geological chart[6] has a legend which gives the following classification for the part of the scale here under consideration:

Northwest margin of Great Illinois coal field.
Subcarboniferous limestone.
Shell stratum.
Cliff rocks of the West ..... } { Coralline beds.
Upper Magnesian limestone ..... } { Lead-bearing beds.
Blue Fossiliferous limestone.
Etc.

On comparing the two editions of the report it becomes evident that a study of Hall's report of the Fourth District of New York, in which a comparison is made with Murchison's Silurian system, convinced Owen that his "Cliff limestone and Blue limestone" were representatives of Silurian rocks.

In the Senate edition of the report as published in 1844, Owen stated:

A review of the fossils of the region under consideration proves that the Cliff formation of Iowa and Wisconsin is, in point of fact, the American equivalent of the Upper, and perhaps of part of the Lower, Silurian formation of Murchison.

It will be remembered that at this time the Lower Devonian, as far up as the Hamilton formation inclusive, was identified with the Silurian

[1] Senate Document 407, page 23.
[2] He had just remarked upon the identity of the Cliff limestone of America with the Scar limestone of England.
[3] Doc. 239, p. 22.
[4] Senate Doc. 407, XXVIIIth Congress, first session. pp. 27–32.
[5] Previously called Archimedes beds.
[6] Pl. 3 of the Senate *document*.

of Murchison.[1] And the identification of the fossils of the Cliff limestone in Iowa, Falls of Ohio, and Illinois, with species of the Onondaga, Corniferous limestones, Marcellus shale, and Hamilton group of New York, was strictly in accordance with the statement above quoted.

I find no evidence in this report of the recognition of the Black shale.

The name "Subcarboniferous limestone," thus introduced by Owen in the Indiana reports of 1839, was again used in the second edition of the "Mineral Lands," and in his final report of 1852 was adopted as the name for the lower division of the Carboniferous rocks of Iowa. Owen considered it the equivalent of the Yoredale series and the Lower Scar limestone of the English geologists.

As we shall see elaborated beyond, Swallow retained the old name "Carboniferous or Mountain limestone" in the Missouri reports of 1855. Hall in the Iowa reports of 1858 retained "Carboniferous limestone." In 1859, in volume 3 of the Paleontology of New York, "Great Carboniferous limestone of the Mississippi Valley" is used. Owen in the Kentucky report of 1856 continued to use "Subcarboniferous limestone," and Worthen in the Illinois reports of 1866 and later used Owen's name "Subcarboniferous." Thus the name became established in American literature. Not only is it inappropriate for the purpose to which it is applied, but it is evident that it was introduced as an expression of confusion and dissatisfaction with the correlation attempted. It probably never would have appeared except for the erroneous correlation of the "Cliff limestone" of the Mississippi Valley with the "Scar limestone" of England. "Scar limestone" was Sedgwick's name for the Carboniferous limestone of the Lake district and Yorkshire; "Cliff" was the American name for "Scar," but the "Cliff limestone" of the Mississippi Valley was found to be, some of it certainly, not Carboniferous, and all of it below the coal-bearing strata, and the prefix "sub" was attached to indicate these facts.

Although we have come thoroughly to understand the application of the name, the substitution of the Mississippian series for it will not, it is believed, do violence to the honor of the early geologists or to the rights of the present and future geologists who will adopt the nomenclature best suiting their purposes.

In 1847 D. D. Owen and J. G. Norwood published a paper entitled "Researches among the Protozoic and Carboniferous rocks of Central Kentucky, made during the summer of 1846." This was noticed in the American Journal of Science.

The reviewer remarked:[2]

> Most if not all of the groups of rocks which occur in New York, from the Genesee slate to the top of the Catskill range, are deficient or obscurely marked in the west, and the Carboniferous rocks rest almost immediately on the schistose beds which represent the Genesee slate; whilst our black slate, and the underlying shell beds of

[1] *See Geol., Fourth Dist.* New York, p. 20.

[2] Am. Jour. Sci., 2d ser., vol. 5, 1847, p. 269.

the Falls of Ohio, with the Goniatite limestone of Rockford, Jackson County, Indiana, as well as the upper shales of Perry County, Tennessee, are the representatives of the Devonian system of Europe.

The reviewer further states: "The *Knob* region, Indiana, Kentucky, Tennessee, Illinois, and Ohio, above the black slate, they show to correspond to the Carboniferous rocks."[1]

In 1847, M. de Verneuil called attention to the necessity of changing the limits of the Cliff limestone and Blue limestone of the Ohio reports. He regarded the upper part of the Cliff limestone as equivalent to the Devonian system of Europe. He announced (in this paper,[2] for the first time, I believe), that "le grand étage des psammites, situé au-dessous du grès houiller et du calcaire de montagne, là où il existe, et que l'on appelait Dévonien, devait être rangé dans le système carbonifère."[3]

Later in the same year, in his paper entitled "Note sur le parallélisme, etc.," he elaborated the same idea.[4]

In the same year, after a visit to this country, M. Verneuil published his important paper in the Bulletin of the Société géologique de France,[5] on the parallelism of Paleozoic rocks. This paper is discussed in a previous chapter (see p. 68). M. de Verneuil's most important contributions to the correlation of the Mississippian series were his positive recognition of the Waverly group of Ohio as Carboniferous, and his demonstration that all the formations from the top of the Black shales upward, and inclusive of the so-called "Carboniferous limestone," for Indiana, Kentucky, Tennessee, and the corresponding beds in the Mississippi Valley, were of Carboniferous age.

Owen's final report did not appear till 1852, but he presented an abstract of its contents before the American Association in 1851.[6] After outlining the lower and "metalliferous rocks" of these States, he mentioned the occurrence in Red River Valley of a "Magnesian limestone," followed by a calcareous formation which he called "Devonian." This was traced westward to Iowa City, thence southeast to the Mississippi River. Between Johnson and Iowa Counties is found an uplift of "Carboniferous sandstone," and "Carboniferous limestone" occurs along the Iowa River, which runs on the extreme eastern margin of the coal field. From Iowa River the Carboniferous rocks bear south through Washington, Henry, and Lee Counties, crossing the Des Moines River and Iowa into Missouri.

---

[1] The original article reviewed I have not seen.—H. S. W.

[2] Lettre sur la géologie des États-Unis. By M. Ed. de Verneuil. Soc. géol. France, Bull., II, vol. 4, pp. 12, 13.

[3] Page 12.

[4] Pages 646–687.

[5] "Note sur le parallélisme des roches des dépôts paléozoïques de l'Amérique Septentrionale avec ceux de l'Europe, suivi d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des étages où elles se rencontrent et terminé par un examen critique de chacune de ces espèces."—Soc. géol. France, Bull., II, vol. 4, pp. 646–709.

[6] Owen, D. D.: Abstract of an introduction to the final report on the Geological Surveys made in Wisconsin, Iowa, and Minnesota, in the years 1847–1850, containing a synopsis of the geologic features of the country. Proc. Amer. Assoc., vol. 5, 1851, pp. 119–131.

The coal field of Missouri and Iowa covers about 35,000 square miles. This western field is very shallow, consisting of three well marked divisions—(1) an upper siliceous, 100 feet; (2) middle argillaceous, 75 feet; (3) lower calcareous, 100 feet. The middle division carries the coal, the coal layers having a thickness of four or five feet.

Passing from the mouth of Iowa River to that of the Des Moines, the "Subcarboniferous limestone" occurs "*with no coal seams.*" There the Mississippi passes through a corner of the Illinois coal field. The limestone thins out here and the Coal Measures rest on "the limestones of Devonian age." At the junction of the Missouri and Mississippi, "Carboniferous limestone" is found which just underlies the lowest workable seam of the Illinois field.

In the same year, in association with B. F. Shumard, Owen published some statistics regarding the fossils obtained during the survey.[1]

The authors found in the Devonian rocks of these States 49 species, included in 26 genera, and in the Carboniferous 120 species, included in 49 genera.

"Of the above genera 5 are peculiar to the Devonian and 36 to the Carboniferous." * * * "Eight genera are common to the Silurian and Devonian, 10 to the Silurian and Carboniferous, 10 to the Devonian and Carboniferous, and 9 are common to the three systems."

Two-thirds of the 39 species from the Devonian rocks between Parkhurst and New Buffalo, on the Upper Mississippi, are identical with those found in the coralline beds of the falls of the Ohio at Louisville and Charleston Landing, Indiana. "Thirteen species are identical with European forms."

Twenty-four of the 120 Carboniferous species found mainly in Iowa, are identical with European species. While over one-half of the Brachiopoda are identical with ("can be referred to") European species, only two out of 52 Crinoids are common to the two countries.

Polyparia are most abundant in the Devonian, while Acephala are most numerous in Carboniferous rocks.

Mr. H. King,[2] in 1851, published a paper in which he commented upon a section running from St. Louis southwest to Iron Mountain and Pilot Knob. He observed that above the so-called "Mountain limestone" or "Yoredale limestone," upon which St. Louis stands, occurs a coal bed having an average thickness of 4 feet. This coal deposit is not an outliner of the Illinois coal basin, but a continuation of it. Passing over the southern point of this basin, we meet again the "Mountain limestone" which the author for convenience named "St. Louis limestone;" he considered it, both from its position and fossils, as strictly Carboniferous. Its thickness was estimated to be between 500 and 600 feet.

[1] Owen, D. D., and B. F. Shumard: On the number and distribution of fossil species in the Paleozoic rocks of Iowa, Wisconsin, and Minnesota. Am. Assoc. Proc., vol. 5, 1851, pp. 235–239.

[2] King, H.: Some remarks on the geology of the State of Missouri. Am. Assoc., Proc., vol. 5, 1851, pp. 182–199

Below this limestone occurs a siliceous sandstone, from 40 to 100 feet thick, which rests upon the second important coal deposit of Missouri, consisting of two beds, sometimes thinning out to a single bed, resembling very much the upper deposit near St. Louis. This is again underlaid by another limestone, some two or three hundred feet thick, and "of Devonian aspect," but with the majority of its fossils Carboniferous. All that portion of the State lying northwest, north, and east of the line starting on the western boundary of the State, near the headwaters of Sac River; thence northeasterly to the junction of the Sac and Osage Rivers; thence to Warsaw and northeasterly to the Missouri River, a few miles west of Jefferson City to Salt River, is classified as "Carboniferous." From thence the line runs south to the Missouri River, to a point opposite our starting place.

Mr. D. Christy,[1] in 1851, gave account of the Goniatite limestone of Rockford, Indiana. The author, having sent a few Goniatites from Rockford to M. de Verneuil, was informed by him that they were "Carboniferous fossils," identical in age with the supposed Mountain limestone of Belgium and England. Dr. D. D. Owen, who had also presented him with some Goniatites from this locality, had reported that they came from the Black slate beneath the Cliff limestone. But further examination proved, as was suggested by M. de Verneuil, that they came from the "Goniatite limestone."

In the vicinity of Queensville unmistakable evidence was found that it was "central in the Black slate" and "above the Cliff limestone." Hence "should the European classification be adopted, this would require us to bring down our range of Carboniferous rocks to within 30 feet of the Cliff limestone."

In a note which appeared in the Proceedings of the American Association[2] Mr. Christy reported that "M. de Verneuil had remarked in one of his letters that these Goniatites, in the structure of their septa, present a curious blending of the forms of the Carboniferous and Devonian Goniatites, which makes them exceedingly interesting; hence his anxiety to ascertain their true geological position."

This note reveals to us the method applied at this early date by de Verneuil in the correlation of geological formations. He already appreciated the historical (or perhaps chronological will more accurately express it) relations of the morphological characters of fossils.

Fossils were not merely "medals of creation" to him, they were remains of organisms which had lived; similarity suggested genetic relationship.

In 1852, Owen published his final report.[3]

[1] Christy D.: On the Goniatite limestone of Rockford, Jackson County, Indiana. Am. Assoc., Proc., vol. 5, 1851, pp. 76–80.

[2] Am. Assoc. Adv. Sci., Proc., vol. 5, p. 180.

[3] Report of a geological survey of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska and Tennessee, by D. D. Owen, United States geologist.

The following generalized section of the "Subcarboniferous limestones of Iowa" appears in this report.[1]

			Feet.
Subcarboniferous limestones.	Upper series.	*f'*. Upper concretionary limestone	25
		e'. Gritstones—contains *Lepidodendra, Calamites*, etc	5
		d'. Lower concretionary limestone—*Lithostrontian*, etc., compact white, usually concretionary, magnesian in places, including the more evenly bedded limestones of St. Louis, with *Melonites*, etc	30
		c'. Gritstone	10
		b'. Magnesian limestone—reticulate corals and *Terebratula Roysii*	10
		a'. Geodiferous bed	30
	Lower series.	*f*. Archimedes limestone, a thin bedded, light gray limestone—*Spirifers, Terebratula Roysii, Orthis*, etc	50
		e. Shell beds—gray crystalline limestone, *Spirifer striatus, cuspidatus, rotundus, Productus punctatus*, and *semireticulatus*, etc	15
		d. Keokuk cherty limestone	15
		c. Reddish brown Encrinital group of Hannibal, Mo., alternating with bands of chert, at base white, crystalline, and semi-oolitic—*Productus cora, Spirifer cuspidatus*, etc.	70
		b. Encrinital group of Burlington, top brown and flesh colored encrinital limestone, with *Pentremites* and *Crinoids*, various beds of limestone, argillaceous and magnesian	60
		a. Argillo-calcareous group, Evans's Falls, at the top a fine-grained buff silliceous rock, containing casts of *Chonetes, Posidonomya, Allorisma, Spirifer*, and *Phillipsia*; Middle, ash-colored, earthy marlites	70

The author described under the name "Cedar River limestone formation" the limestones of Red Cedar and Iowa River Valleys, Iowa, and referred them to the Devonian age.[2]

On the map the legend classifies this "formation of Cedar Valley" as follows:

Hamilton and Onondaga limestone.....
- *c*. Upper Coralloid limestone.
- *b*. Middle shell beds.
- *a*. Lower Coralline beds.

The author recorded no evidence of the Black shale in the States reported upon.

In the fall of 1855 G. C. Swallow, as State Geologist, published the "first and second annual reports of the Geological Survey of Missouri." The first annual report was made in 1853, but was merely a short report of progress.

In the Survey work, F. Hawn, G. C. Pratt, G. C. Broadhead, B. F. Shumard, and F. B. Meek assisted. Dr. Litton furnished a chemical report on some of the principal mines. The maps and charts were drawn by R. B. Price. Messrs. Meek, Hawn, and Shumard each furnished reports on the special work assigned him, and the classification in the main report is in some cases at least suggested by the studies of these assistants. In the generalized section, opposite page 60, the following classification of the Upper Paleozoic is given:

[1] Report of a geological survey of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska and Tennessee, by D. D. Owen, United States geologist.

[2] *Ibid., p. 77.*

			Feet.
System III. Carboniferous	Coal Measures, *e*....	Upper Coal series.....	275
		Middle Coal series	225
		Lower Coal series.....	140
	Carboniferous or Mountain limestone	*f*. Ferruginous sandstone....	195
		g. St. Louis limestone	200
		h. Archimedes limestone....	200
		i. Encrinital limestone	500
System IV. Devonian....	Chemung	*j*. Chouteau limestone.....	70
		k. Vermicular sandstone and shales.....	75
		l. Lithographic limestone ..	60
		p. Hamilton group.....	50
		m. Onondaga limestone	75

The Coal Measures is overlaid by *d*, Drift, and the Onondaga limestone is underlaid by Delthyris shaly limestone. The term "Ferruginous sandstone" appears to have been first applied here in a technical sense and defined by Prof. Swallow[1] and first applied to the rocks in the bluff near Salt Creek, Sulphur Springs, near Osceola. St. Louis limestone had been used as a general term, and was technically applied by Dr. Owen as a discovery of Dr. Shumard in 1849. Archimedes limestone had been used already by Dr. D. D. Owen in 1852. The name Encrinital limestone was also suggested by Owen in 1852, who spoke of the Encrinital group of Hannibal, Missouri, which was also Swallow's typical locality.[2] Prof. Swallow applied the name "Chemung" to the group of strata including the Chouteau limestone, Vermicular sandstone and shales, and Lithographic limestone. It is placed stratigraphically at the base of the Carboniferous system. In a foot-note he says:[3]

> There is some difference of opinion respecting the system to which this group belongs, but if we make a division of the Missouri rocks into Devonian and Carboniferous, the line of separation most distinctly marked is between the Encrinital and Chouteau limestones.

Six pages later a new section begins with the following:

> *System IV, Devonian.*—Two formations of this system exist in Missouri: *Hamilton group, Onondaga limestone.*

Mr. Meek stated in his report that the stratigraphical position of *j*, *k*, and *l*, "taken in connection with their organic remains, leaves little room to doubt that they represent the Chemung group of New York," and "I am far from considering it a settled question that we should not carry up the Devonian so as to take in the Chouteau limestone."[4]

As well as the fact can be determined by the literature, Prof. Swallow was the first to correlate these rocks with the Chemung group of New York. The rocks themselves had been included in the Carboniferous by Owen in 1852, under the name "Argillo-calcareous group of Evans Falls." Neither Messrs. Swallow nor Meek was fully satisfied in placing them in the Devonian. But it was James Hall who settled the correlation by identifying Owen's "Argillaceous group" of Iowa with the Chemung (Devonian) of New York, and recognized the same formation in the section at Hannibal, Mo. This was in harmony with his correla-

[1] Owen's Report, pt. 1, pp. 91, 92. [2] Ibid. pt. 1, p. 101. [3] Ibid., pt. 1, p. 101. [4] Ibid., pt. 2, p. 103.

tion of the Waverly with the Chemung.[1] Later, when Mr. Meek had become better acquainted with fossils, he corrected the mistake.

"Chouteau group," the name proposed later by Mr. Broadhead in 1879, is a proper designation for the rocks in question, and had Swallow proposed it in 1855, the name Kinderhook group would have been superfluous.

In the report of the Geological Survey in Kentucky,[2] made in 1854 and 1855, by D. D. Owen, principal geologist, and printed in 1856, the "Anvil Rock" is named and defined.

The name is applied to a massive sandstone separating the Lower Coal Measures from the Upper Coal Measures of southwestern Kentucky. The title is a popular one originally applied to an immense mass of the sandstone, which has somewhat the form of an anvil, in Union County, Kentucky, a figure of which is given.[3] The name was extended to the sandstone formation of which this rock was a part.

In this volume the term "Subcarboniferous" is applied to the limestone below, separated from the Coal Measures by sandstones, shales, and conglomerates, which together are regarded as representing the "Millstone grit." The "Subcarboniferous" includes "Archimedes limestone" of the Dismal Creek section and "limestones with Pentremites and Archimedes" of other sections.

The author[4] subdivides the "Subcarboniferous" into—

1. Archimedes and Pentremital limestone.
2. Lithostrontion or Barren limestone group.
3. The lower part of this is more argillaceous and may constitute a third division.
4. Subcarboniferous sandstone (Jefferson and Bullitt Counties). This is the Knob formation. Under this lies the "Black Lingula shale," "Coralline Falls limestone," "Chain Coral and Magnesian limestone," and "Blue Shell limestone marl."

In 1856,[5] in the Subcarboniferous limestones near Warsaw, A. H. Worthen discovered the remains of fish in considerable abundance, and later two other beds were found lower down in the series.

The upper fish bed is situated in the Lower Archimedes limestone, the fossil remains consisting entirely of palate teeth. At the base of this limestone is the middle bed, in which the more abundant remains are mostly jaw teeth, with a few palate teeth and spines.

The lower bed was first observed in Quincy, Illinois, near the top of the Burlington Crinoidal limestone, and subsequently in Henderson County, Illinois, and at Augusta, Iowa. As the fossil remains in this bed are much smaller than those mentioned above, the author inferred

[1] See Geol. of Iowa, vol 1.

[2] Report of the geological survey in Kentucky, made in 1854 and 1855. By D. D. Owen, principal geologist, Frankfort, Kentucky, 1856.

[3] Ibid., Pl. III, opp. p. 45.

[4] Ibid., pp. 81, 82, 89, 90, 91, 95, 97, 98.

[5] Worthen, A. H.: On the occurrence of fish remains in the carboniferous limestone of Illinois. Am. Assoc., Proc., vol. 10, pt. 2, 1856, pp. 189-192.

that the Subcarboniferous fish increased greatly in size during this period. In the southern extension of the Pentremital and Archimedes limestone into Tennessee and Alabama, these remains are exceedingly rare.

In 1856 James Hall[1] read a paper before the American Association, an abstract of which was published in the American Journal of Science. His object was "to show that there are certain well marked subdivisions in the Carboniferous limestone of the Mississippi Valley."

The article appears to be a preliminary account of chapters which appeared later in his Report on the Geology of Iowa.

In the following table are expressed the correlations which he proposed, showing the "true order of superposition among the different members of the limestone series:"

VII. Coal Measures.		
VI. Kaskaskia limestone, or Upper Archimedes limestone.	of	Kaskaskia and Chester, St. Mary's, Missouri.
V. Gray, brown, or ferruginous sandstone, overlying the limestones of Alton and St. Louis.	of	Below St. Genevieve, Missouri. Between Prairie du Rocher and Kaskaskia, Illinois.
IV. "St. Louis limestone," or "Concretionary limestone."	of	St. Louis; highest beds below Keokuk. Alton; St. Genevieve.
III. "Arenaceous bed," Warsaw or Second Archimedes limestone.	of	Warsaw and above Alton, Illinois; Keokuk, Iowa.
"Magnesian limestone,"—Spergen Hill, Bloomington, Iowa.		
Beds of passage, soft shaly or marly bed with geodes of quartz, chalcedony, etc.		
II. Keokuk limestone, or Lower Archimedes limestone.	of	Keokuk, Quincy, Illinois, etc.
Beds of passage, cherty beds 60 to 100 feet. Rapids above Keokuk.		
I. Burlington limestone	of	Burlington, Iowa; Quincy, Illinois; Hannibal, etc., Missouri.

The formations I to VI, inclusive, constituted the "Carboniferous limestone;" next below them he reported the

Oolitic limestone and argillaceous sandstone of the age of the Chemung group of New York.	of	Burlington, Iowa; Evans Falls, and Hannibal, Missouri.

He correlated the "Argillo-calcareous group" of Owen and the "Chouteau limestone" of Shumard and Swallow with the "Chemung group" of New York, stating that "the higher beds contain the same fossils as the Chemung group of New York and elsewhere, and have been carefully traced throughout the intermediate space."[2]

He thought the "green shale" of the Burlington section and the "ash-colored earthy marlites" of Evans Falls "should be referred to the Portage group. * * * It is likewise probable that the lithographic limestone of Prof. Swallow will be found more closely allied to the Hamilton than to the Chemung group."

The name "Burlington limestone" was proposed to include what Owen had called the "encrinital group of Burlington," and "reddish-

[1] Hall, James: On the Carboniferous limestones of the Mississippi Valley. (Abstract.) Am. Jour. Sci., vol. 23, 1857, pp. 187-203.

[2] Ibid., p. 189.

brown encrinital group of Hannibal," and what Swallow and Shumard had called the "encrinal limestone" in Missouri.

Owen's name "Keokuk cherty limestone," with "cherty" omitted, is adopted for the next division, and the author writes, "the so-called siliceous formations of Tennessee and Alabama are of the same strata."[1] This division includes the three divisions *d*, *e*, and *f* of Owen's classification, viz, the "Keokuk cherty limestone," the "shell beds," and the "Archimedes limestone."

Omitting the "Geodiferous bed" of Owen as "beds of passage,"[2] Hall applied the name "Warsaw or Second Archimedes limestone" to the "Magnesian limestone" and "Gritstone" of Owen. The next higher division is called the "St. Louis limestone."

D. D. Owen, in a letter[3] to M. de Verneuil, referred to the discovery by Shumard of the "St. Louis limestone" which, Owen thought, "belonged in the lower part of the Carboniferous limestone." This appears to be the earliest announcement of the St. Louis limestone in the scientific sense. The name was definitely proposed and defined by Dr. H. King of St. Louis in 1851,[4] and in Owen's table the "lower concretionary limestone" includes the "limestone of St. Louis."

Above the St. Louis limestone is reported the "Ferruginous sandstone" of Missouri. Owen did not report such a member, but for the overlying limestone series (composed of heavy-bedded limestones, and generally alternating with marl, shale, limestones, and a few beds of sandstone), Hall proposed the name "Kaskaskia limestone or Upper Archimedes limestone." This formation was found both at Kaskaskia and at Chester, Illinois, and below St. Genevieve in Missouri, and according to A. H. Worthen had been examined, its position clearly determined, and reported upon under the name "Chester limestone"[5] by himself in 1853. It is probable that Owen did not recognize this higher limestone, and that his "*f'*, upper concretionary limestone," may be only a continuation of the "lower concretionary," *d'*, separated from it by a more or less local sandstone, *c'*.

Evidence was given of extensive denudation previous to the coal period, and the author mentioned as consequences of this ancient denudation, the coal deposits in depressions among the inclined strata of the Silurian rocks; also rounded masses of clay found in the limestones of the Hamilton and Upper Helderberg groups, and he concluded from examination that these masses of clay and coal deposits were made subsequently to the deposition of the limestone, filling cavities caused by denudation.

In conclusion, a few words express the general features of the series

[1] Hall, James: On the Carboniferous limestones of the Mississippi Valley. (Abstract.) Am. Jour. Sci., vol. 23, 1857, p. 190.

[2] In the final Report on the Geology of Iowa, 1858, this bed is included with the Keokuk limestone, p. 96.

[3] Dated January 14, 1849, and published in the Bull. Soc. géol. France, II, vol. 6, pp. 419–441.

[4] *Proc. Am. Assoc. Adv. Sci.*, vol. 5, p. 185.

[5] *See Geol. of Illinois*, vol. 1, p. 41.

of limestones on the south of the Ohio River. All the members of these limestones thin out, with the exception of the "Kaskaskia limestone," which predominates over the whole country, and is there the great "Carboniferous limestone."

In 1857 Owen[1] recognized the following classification at the Falls of Ohio:[2]

1. Black bituminous shale.
2. Upper Crinoidal, shell, and coralline limestones above.
3. Hydraulic limestone.
4. Lower Crinoidal, shell, and coralline limestones.
5. Olivanites bed.
6. *Spirifera gregaria* and shell and coralline beds.
7. Main beds of coral limestone, resting upon the "chain coral limestone" (Niagara).

In the base of No. 2, on Conn Island, fish remains were found, and this stratum is called the "Upper Fish bed." A lower fish bed was seen at the base of No. 6, called the "Turbo bed" in general, the subdivisions of which are given as follows of Nos. 6 and 7:

6.	Shell beds	A. *Conocardium bed.*	inches..	7
		B. *Leptæna bed*	feet..	6
	Parting chert layers		do...	3
	Coral layers		do...	7
	Very hard rock		do...	2
7.	Main *coral beds*	1. Dark gray bed.		
		2. Black coralline layer.		

This rests upon the (Niagara) "chain coral bed."

G. C. Swallow[3] gave a brief description of the formations of Missouri and the contained minerals. He reported that the stratified rocks of Missouri belong to the following divisions, enumerated in descending order:

I. Quaternary.
II. Tertiary.
III. Cretaceous.
IV. Carboniferous.
V. Devonian.
VI. Silurian.

In giving a detailed account of each system, he considered the Carboniferous as presenting the following divisions:

(1) Upper Carboniferous or Coal Measures.
(2) Lower Carboniferous or Mountain Limestone.

The upper series is made up of sandstones, limestones, and shales, amounting to 1,500 feet in thickness, containing numerous beds of iron ore and ten beds of workable coal. The lower series, about 1,745 feet in thickness, includes "Chester limestone," "Ferruginous sandstone," "St. Louis limestone," "Archimedes limestone."

---

[1] Geological survey of Kentucky, second annual report, 1857.
[2] Ibid., p. 97.
[3] (Explanations of the geological map of Missouri, and a section of its rocks. Proc. Amer. Assoc., vol. 11, pt. 2, 1857, pp. 1–21.

In the report of the geological survey of Iowa, a systematic study of the fossils of the Mississippian series was applied in the differentiation of the several formations.[1]

The geological formations of the upper Paleozoic were classified in the following manner by James Hall:

Above the Le Claire limestone comes a hydraulic, drab-colored limestone and shales with cavities, called the "Onondaga salt group"; next above this a limestone, gray and ash-colored, subcrystalline, also containing cavities, and with shaly partings, called the "Upper Helderberg;" following this is an argillaceous limestone or calcareous shale called the "Hamilton," which in some places is an alternation of calcareous shales and limestones, but is said to be more calcareous at the bottom. A stratum 10 to 15 feet thick at Rockingham and New Buffalo is called the "Encrinal limestone." Next above are shales and soft sandstones, as at Pine Creek, called the "Chemung." The order observed at this last mentioned place for the Chemung is "shaly limestone, green shale, sandy beds, yellow sandstone." At Davenport, Burlington, etc., the Chemung is described as "gray and yellow sandstone with shaly partings." Sometimes it is underlain by green shales, which are called the "Portage group."[2]

The typical section of this part of the series is at Burlington, Iowa.[3] It is as follows:

(1) Soft green shale. (2) Fine grained siliceous and argillaceous sandstone. (3) Limestone and shale, siliceous. (4) Argillaceous sandstone with Chemung fossils. (5) Oolitic bed. (1–5—"Chemung group".) (6) Calcareous and argillaceous shale, beds of passage. (7) Cherty beds. (8) Burlington limestone, brownish or grayish-brown encrinal limestone, the higher beds more or less white and subcrystalline, and in places 72 feet thick.

This Burlington limestone was regarded by Hall as equivalent to the "Encrinital limestone" of Owen of Missouri. It thickens southward.

Following the "Chemung" occurs a light gray or brownish white crinoidal, subcrystalline limestone called the "Burlington limestone." Upon this comes the "Keokuk limestone," a shaly grayish or bluish crinoidal limestone, which the author regarded as an equivalent of the "Archimedes limestone" of Owen and the "Siliceous group" of Tennessee. The Keokuk is followed by a geode bed and this by the "Warsaw limestone or second Archimedes limestone," which is "a magnesian limestone, shale and shaly limestone, thin-bedded and arenaceous," and after this a "coarse yellow calcareous sandstone and some pebbles of quartz." Next comes the "St. Louis limestone" of Swallow or "Concretionary limestone" of Owen. This is a brecciated, ash colored limestone, and sometimes subcrystalline and granular in texture, becoming more com-

[1] Report on the Geological Survey of the State of Iowa, embracing the results of investigations made during portions of the years 1855, 1856, and 1857, by James Hall and J. D. Whiting, vol. 1, Albany, 1858. 8vo., xv, 724, 4, and 30 pp., 29 plates, plate of section, and 2 maps.

[2] Ibid., p. 89.

[3] *Ibid., pp. 89–90.*

pact on going southward. Hall speaks of "the brecciated character of the northern exposures of the St. Louis limestone," and of the "more or less diagonally laminated limestone of gray to white color" in the more southern part.[1]

Below St. Louis, along the valley of the Mississippi, from Prairie du Rocher to Chester, the series dipping gradually southward exposes the "St. Louis limestone," with the "Ferruginous sandstone" resting on it, and above this the "Kaskaskia limestone." Hall observed the fact that the limestones thin out toward the north and upon their inclined edges are followed unconformably by the Coal Measures. He drew from this the inference that a contraction of the borders of this sea at the north began with the deposition of the Carboniferous limestone; that this was consequent upon the uplifting of the older rocks at the north.[2]

The limestone of the UpperCoal Measures in Ohio is traced westward, and is regarded as represented by the Carboniferous limestone of the Rocky Mountains. Previously, in the Report on the Mexican Boundary, Mr. Hall had recognized the fact that the Rocky Mountain region must have been an open sea at the time the Coal Measures were being deposited in the Mississippi Valley and farther eastward. The oscillation during the time of the Carboniferous limestone was mainly upward for the Upper Mississippi basin, and during the Coal Measures Worthen shows[3] that the same region was gradually sinking, causing the higher Coal Measures to extend farther northward than those below.

In the classification of the rocks of Iowa it was quite natural that the New York series should take a prominent part in the nomenclature. Although fossils were considered in the correlation, the erroneous interpretations, as well as the reports themselves, show that the lithologic characters of the various rocks were considered of chief importance. As Worthen stated in the First Report on the Geology of Illinois, in regard to the beds in Indiana, Iowa, and Missouri, which had been referred to the "Chemung group" of New York, the identifications were "made purely on lithological grounds."[4] It was this dominant idea, that there should be some similarity in the character of the rocks of the corresponding zones in separate regions, that led to the importance of the "Ferruginous sandstone" of the Missouri and, later, of the Iowa Reports.

Again, the "Siliceous group" in Tennessee and Alabama was regarded as important because probably representing a corresponding Siliceous group in the English classification.

The "Carboniferous or Mountain limestone" was distinctly recognized in the upper Mississippi region, and a "Millstone grit" was needed to fill out the system as interpreted in England. It can not be denied that great masses of limestone or of sandstone can be traced satisfactorily for hundreds and may be thousands of miles along the geological outcrops, but this expresses only the fact that, for long geological periods,

[1] Geol. Surv. Iowa, Rep., p. 105.
[2] *Ibid., p. 117.*
[3] Geology of Illinois, vol. 1, p. 50.
[4] Ibid., p. 100.

the general relations of oceans and continents remained substantially the same. When, however, the attempt is made to trace the subdivisions and to correlate series and stages and the lesser zones of the geological classifications by lithologic means, then the inadequacy of the method becomes apparent. As we look over the history of the work of geologists in America, we find the majority, and for the field I have specially studied I am inclined to say nearly all, of the erroneous correlations are directly traceable to a too great dependence upon lithology.

The following exhibits the classification of the Carboniferous limestone of Iowa, Illinois, and Missouri as it was understood by Hall in 1858.[1]

COAL MEASURES OF IOWA, ILLINOIS, AND MISSOURI.

VI. Kaskaskia limestone, or Upper Archimedes limestone. Pentremital limestone.	Kaskaskia and Chester, Illinois. St. Mary's, Missouri.
Lower arenaceous beds of passage.	
V. Gray, brown, and ferruginous sandstone overlying limestone of St. Louis and Alton.	Below Ste. Genevieve, Missouri. Below Prairie du Rocher and Kaskaskia, Illinois.
Abrupt passage.	
IV. St. Louis limestone, Concretionary limestone.	Highest beds below Keokuk, Alton, St. Louis, Ste. Genevieve, Prairie du Rocher.
Passage arenaceous or indistinct.	
III. Arenaceous bed, Keokuk and northward. Warsaw limestone or Second Archimedes limestone. Magnesian limestone.	Warsaw and Alton, Illinois. Bloomington and Spurgen Hill, Indiana. Opposite Fort Madison, Mount Pleasant.
Passage soft, marly, geodiferous. Geode bed, Keokuk, Nashville, Iowa, and Warsaw, Illinois.	
II. Keokuk limestone, Lower Archimedes limestone. Archimedes limestone, Owen and Swallow.	Keokuk and Mount Pleasant, Iowa. Quincy, Illinois. Hannibal, Missouri.
Passage cherty limestone, 60 to 100 feet.	Rapids above Keokuk, Iowa. Quincy, Illinois.
I. Burlington limestone	Burlington, Iowa, Quincy, Illinois, Hannibal, Missouri.
Oolitic limestone, sandstone, and shale of Chemung and Portage groups of New York.	Burlington and Evans Falls, Iowa. Hannibal, Missouri, etc.

In 1859 Mr. A. H. Worthen[1] reported the discovery of a terrestrial flora in the Chester limestone group.

While constructing a section of the Ohio Bluffs he discovered, in 1851, in the middle of the Chester limestone of Pope County, a bed of calcareo-argillaceous material containing fossil plants. The flora does not present a single species in common with the Carboniferous. Among the plants he found representatives of the genera *Stigmaria*, *Sigillaria*, *Knorria*, and *Lepidodendra*, but of species quite distinct from those in the Coal Measures.

"This fact seems to indicate the close proximity of an ancient coast line in this direction," and its probability is increased by the fact that "the Subcarboniferous series thins out rapidly to the north and east."

[1] *Geology of Iowa*, p. 109.

[1] *Worthen, A. H.*: Remarks on the discovery of a terrestrial flora in the Mountain limestone of Illinois. *Am. Assoc., Proc.*, vol. 13, 1859, pp. 312, 313.

In 1859[1] James Hall presented his view of the relation of the strata of the Mississippi Valley to those of the New York section. The interval between the Chemung and the Coal Measures of the Appalachian section is filled, in the West, by the representatives of the Carboniferous limestone. The following table explains this view:[2]

New York and Pennsylvania Coal Measures.		Mississippi Valley Coal Measures.
Red shales Conglomerate Catskill Mountain group	Great Carboniferous limestones of the Mississippi Valley.	Kaskaskia limestone. Ferruginous sandstone. St. Louis limestone. Warsaw limestone. Keokuk limestone. Burlington limestone.
Chemung and Portage groups		Chemung and Portage groups.
Hamilton group		Hamilton group.

Concerning the fauna of the Western rocks, which he regarded as the equivalent of the Chemung and Portage groups, he reported that he had traced the rocks through Ohio, and then from Indiana into Michigan, across Indiana and Illinois to Iowa, and into Missouri. He recognized scarcely a single species identical, but found representative forms.

It will be seen thus that the dominant means of correlation was the strata, probably the black shale and the argillaceous and arenaceous deposits following below the limestone. The suggestion was thrown out that the cause of the great difference in sedimentation is the elevation of the Cincinnati axis, allowing a sea to be depositing calcareous sediments in the Mississippi Valley, while a coarse deposit was being made east of that axis.[3] This is evidently the true explanation.

It was the wide territory which American geologists had to study which led them to recognize the great difference in the conditions which existed at the same geological time in separate regions of the continent, and developed that minute comparative study of fossils which alone has made exact correlation possible.

In the above table it is evident that up to this time Professor Hall still held to the view that the Chemung Group of Iowa, Missouri, and Illinois was, as he called it, "Subcarboniferous," that is, was below the "Carboniferous formations," not one of them.

In 1860 Sydney S. Lyon[4] recognized three divisions, viz: "(1) Coal Measures, (2) Millstone grit series, (3) Subcarboniferous series;" but in the latter, the lower or "Subcarboniferous series," he follows the erroneous usage introduced by Owen, for we find included under this division not only the lower Carboniferous rocks, but all from the "Black slate" to the "Catenipora beds," inclusive. "Subcarboniferous series" applied to the rocks below the Millstone grit is a modification of Dr. Owen's usage. Owen proposed the name "Subcarboniferous limestone," but applied it in about the same sense in which Mr. Lyon applied the name "Subcarboniferous series." Mr. Lyon restricted the use of the

[1] Paleontology of New York, vol. 3. [2] Ibid., p. 53. [3] Ibid., p. 58.
[4] Discussion of the Stratigraphical Arrangement of the Rocks of Kentucky. Trans. St. Louis Acad. Sci., vol. 1, 1860, pp. 612-621.

former term to the limestone which Prof. Hall called "Carboniferous limestone."

Mr. Lyou's classification was as follows:[1]

	Feet.	
a. Coal Measures	1,200	
b. Fifth sandstone	40–100	Millstone grit series.
c. Fourth limestone	10– 40	
d. Beds of colored clays	0– 84	
e. Fourth sandstone	0– 6	
f. Third limestone	25– 50	
g. Aluminous shale	0– 53	
h. Third sandstone	25– 40	
i. Second limestone	25– 50	
k. Second sandstone	75– 90	
l. First limestone	15– 20	
m. First sandstone	10– 30	
n. Cavernous limestone	200–400	Subcarboniferous series.
o. Middle limestone	500–600	
p. Sandstones and shales	205–300	
q. Black slate	50–100	
r. Encrinital limestone	0– 8	
s. Hydraulic limestone	0– 20	
t. Spirifer bed	0– 3	
u. Nucleocrinus bed	0– 2	
v. Turbo bed	6– 10	
w. Coral bed	5– 10	
x. Catenipora beds	15– 40	

The divisions *p*, *o*, *n*, constituted what he called "Subcarboniferous limestone," the synonyms for which were "Barren limestone," "Cavernous limestone," "Carboniferous limestone," and "Mountain limestone" of the Europeans.

Division *o* was the middle member of the Subcarboniferous limestone, and 180 feet above its base is a bed which was regarded as equivalent to Hall's "Spurgen Hill beds," of Washington County, Indiana, which Prof. Hall considered as equivalent to the "Warsaw limestone."

The lower member of the "Subcarboniferous limestone" (*p*) "is frequently distinguished as the *Knobstone beds*."[3] The "Black slate" with *Lingulas* (*q*) the author put in the "Devonian," and he stated that division *p* has been also placed in the Devonian, but that the paleontologic evidence of the Goniatite beds at Rockford, Indiana, would point to its inclusion with the Subcarboniferous limestones, instead of in the Devonian.[4]

The beds *r*, *s*, *t*, *u*, *v*, *w*, *x*, "thin out rapidly and disappear entirely about twenty miles south of Louisville."[4]

This classification was in accord with the general usage of Dr. Owen and those who had assisted him in his surveys in the Mississippi Valley.

James Hall, in the various papers in which he attempted to correlate the Western deposits with his New York system, used the name "Carboniferous limestone" for the calcareous portion of the "Subcarboniferous series" of Owen, and applied "Subcarboniferous" to his so-called "Chemung group," which in New York is of Devonian age. The Western geologists clearly understood the relation of the so-called "Chemung" of the Mississippi Valley to these "Carboniferous limestones,"

[1] *Discussion of the* Strategraphical Arrangement of the Rocks of Kentucky. Trans. St. Louis Acad. Sci., vol. I, 1860, p. 641.

[2] *Ibid., p. 617.* [3] Ibid., 619. [4] Ib., p. 620.

but they were not so well acquainted with the Chemung group of New York. This is shown by the fact that Swallow and Meek, in the Missouri report of 1885, placed the Chemung above the "Devonian,"[1] although in tabulating it they bracketed the Chemung with the Devonian. However, to the State geologist of New York the "Chemung" was unmistakably Devonian, and for him to correlate deposits in the West with the Chemung necessitated placing them below the Carboniferous system; hence he used the term "Subcarboniferous" to separate these deposits from the Carboniferous system above, whereas the Western geologists included the Subcarboniferous limestone in the Carboniferous system to distinguish the lower series, which was under the true carbon-bearing Coal Measures.

Mr. A. Litton[2] in 1860 reported some statistics regarding thickness of deposits derived from a well boring in St. Louis.

A description of the boring is given, beginning in the St. Louis limestone and penetrating to a depth of 2,199 feet, passing through the limestones, cherty rock, and shales of the Carboniferous system, 650 feet, the red marls and the shales of the "Chemung," the limestones, shales, sandstones, etc., of the Hudson River, Trenton, and Black River groups, and finally the magnesian series. The white, soft sandstone found at a depth of 1,505 feet is considered as the Saccharoidal sandstone; from that the main supply of water was obtained, none rising to the surface from below this sandstone.

Mr. C. A. White contributed a paper[3] on the rocks at Burlington, Iowa, in 1860, in which he called attention to the close relationship between the faunas in the "Chemung" rocks in the lower part and those in the upper rocks of the Burlington section. He noticed also that the Brachiopods of the "Chemung" were very similar and possibly of identical species in some cases with those above the Burlington limestone. He suggested (p. 225–6) that although the so-called Chemung rocks of Iowa may be geologically equivalent to the Chemung of New York they are not contemporaneous; migration of the species westward having taken place at the close and after the time of the Upper Chemung of New York.

W. B. Rogers, commenting upon this paper,[4] remarked on the gradual passage from a Devonian to a Carboniferous fauna on passing westward from the Appalachians, previously suggested by James Hall. He suggested that "the mingling of races in successive formations is a natural result of the accumulations of the strata during a long period of comparative repose," and said further:[5]

> The changes of fossil faunas are more gradual in proportion to the degree in which the successive deposits of a given period have been preserved from destruction.

[1] See text of the report (vol. 1–2, Pt. 1, p. 101, and Pt. 2, p. 101.

[2] Litton, A.: Belcher & Brothers' artesian well in St. Louis, Missouri. St. Louis Acad. Sci., Trans., 1857, vol. 1, 1860, pp. 80–86, plate.

[3] Observations upon the geology and paleontology of Burlington, Iowa, and its vicinity, by Charles A. White. Sept., 1860. Boston Journ. of Nat. Hist., vol. 2, pp. 209–235.

[4] Proc. Boston Soc. Nat. Hist., vol. 7, 1861, p. 320.

[5] Ibid., p. 321.

He would correlate the calcareous and associated beds below the Burlington and possibly all below the Keokuk with the Ponent or Catskill and Vespertine, represented by 6,000 feet of deposits in the Appalachian region. He adds:

> But all such attempts at synchronizing distant deposits must be limited to a general and vague result, even when corresponding fossils would seem to mark simultaneous origin, and we must not forget the large agency of migration, and the long lapse of years, which in many cases may have been required for the extension of a living race into distant submarine settlements.

Messrs. C. A. White and R. P. Whitfield, in the introduction to their paper[2] on the Chemung rocks of the Mississippi Valley, which is mainly descriptive of species, state their reasons for recognizing the "Chemung" in Iowa. They say the Hamilton group of New York is recognized in Illinois and Iowa as a reliable Devonian horizon by the fossils; that the Chemung offers changes even in short distances. In northeastern Ohio they hold that there are few if any species common with those of New York, and the fauna in western Ohio and Michigan is still different, but still the Chemung age of each is maintained. It is thus apparent that to these authors the correlations in the West were based upon relative stratigraphic position, the generic relations of the fossils, together with a not unremarkable similarity of lithological characters.

Some species of the "Chemung" of Burlington, Iowa, are said to be the same as those of the "Chemung" of Ohio, "which rocks can be traced continuously to New York."[3]

Notwithstanding an unmistakable resemblance to Carboniferous fauna, they refer them to the Chemung of New York, explaining that "a direct continuity of strata of the Chemung of New York can be traced from that State to those of Ohio." Thus it appears that Messrs. White and Whitfield, relying upon the correctness of the determination of continuity of strata claimed by Hall in 1842 were led to put aside the evidence of fossils, and to explain the differences as due to geographic causes.

Messrs. Meek and Worthen, in their discussion of this question, made the want of specific identity the chief reason for separating the Burlington rocks called "Chemung" from the Chemung of New York,[4] and their reliance upon the Carboniferous aspect of the fossils led them to correctly correlate the formation which had hitherto been called "Chemung."

Messrs. W. H. Niles and Charles Wachsmuth,[5] maintained that the

---

[1] Proc. Boston Soc. Nat. Hist., vol. 7, 1861, pp. 321, 322.

[2] Observations on the Rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species from the same horizon at Burlington, Iowa. By R. P. Whitfield and C. A. White. Boston Soc. Nat. Hist., vol. 8, 1862, pp. 289–306.

[3] Ibid., p. 290.

[4] Remarks on the age of the Goniatite limestone at Rockford, Indiana, and its relations to the "Black slate" of the Western States, and to some of the succeeding rocks above the latter. By F. B. Meek and A. H. Worthen. 1861. Am. Jour. Sci., 2d ser., vol. 32, pp. 167–177 and 288.

[5] Evidence of two distinct Geological Formations in the Burlington Limestone. Am. Jour. Sci., vol. 42, 1866, pp. 95–99.

Burlington limestone is divided into two distinct formations, which they called the "Lower" and "Upper Burlington limestone." The two sections can be distinguished from each other by their lithologic characters alone, but the distinction chiefly depends upon the different kinds of crinoids found in the two divisions. In the lower section its upper strata become interstratified with beds of chert, and the uppermost stratum of chert forms the division between the two sections. The crinoids below this cherty bed are smaller, less coarse in their general features, and the ridges, spines, etc., are never so prominent as in the species of the upper division. The inference is, that circumstances were not so favorable to the growth of these animals during the deposition of the lower strata. There is a similar marked distinction between the crinoids of the Upper Burlington and those of the Keokuk limestone, the latter being still larger in size and more prominent in feature. A band of chert is also found between the Upper Burlington and the Keokuk, and it appears from these facts that there was something in the presence of siliceous material in the depositing waters during the formation of the upper beds of both the Lower and Upper Burlington divisions which was unfavorable to the growth and life of the inhabiting crinoids, for as the chert appears the crinoids seem to have declined, and finally all species became extinct before the completion of the chert. The same fact is found true of the Mollusca, most of the species of the two divisions being distinct. Lists of some of the better-known species of the crinoids are appended, arranged under the names of the formations to which they are exclusively restricted.

If the view of the authors were found to be correct in fact, it would signify that the cherts had their origin during the original deposition of the rock, but even were it a fact, it may be questioned whether the difference in fauna was not purely local, conditioned upon changed character of the bottom.

The series of Reports of the Geological Survey of Illinois,[1] by Mr. A. H. Worthen as Director, began with vol. I., in 1866.

In the classification of the rocks of Illinois, the New York nomenclature was used for the subdivisions of the Silurian and Devonian

[1] Geological Survey of Illinois, A. H. Worthen, Director.

Vol. I. Geology. 1866.

Vol. II. Paleontology, Descriptions of Vertebrates, by J. S. Newbury and A. H. Worthen. 1866. Descriptions of Invertebrates, by F. B. Meek and A. H. Worthen. Description of Plants, by Leo Lesquereux.

Vol. III. Geology and Paleontology. 1868. Geology, by A. H. Worthen. Paleontology, by F. B. Meek and A. H. Worthen.

Vol. IV. Geology and Paleontology. 1870. Geology, by A. H. Worthen. Paleontology, Vertebrates, by Newberry and Worthen. Plants, by Lesquereux.

Vol. V. Geology and Paleontology. 1873. Geology, by Worthen and James Shaw. Paleontology, by Meek and Worthen.

Vol. VI. Geology and Paleontology. 1875. Geology, by Worthen, G. C. Broadhead, E. T. Cox. Paleontology, by O. St. John, Worthen, and Meek.

Vol. VII. Geology and Paleontology. 1883. Geology, by A. H. Worthen. Paleontology by A. H. Worthen, Orestes St. John, and S. A. Miller, with an addenda by Charles Wachsmuth and W. H. Barris.

systems, and for the Carboniferous system the nomenclature already proposed in the Missouri (1855) and Iowa (1858) Reports was adopted with some modifications.[1]

In classifying the Carboniferous rocks, Worthen included the "Barren Coal Measures" or "Millstone grit" in the Coal Measures. They are seen in the southern part of the State, but not in the more northern part, where the Coal Measures proper or "Upper Coal Measures" outcrop. They are terminated by a sandstone called the "Anvil rock sandstone" (Owen), upon which are some limestones regarded as equivalent to the "Great limestone of Pennsylvania."[2]

Worthen adopted the name "Subcarboniferous limestone" for the rocks between the Black slate and the Coal Measures and Conglomerate.

The following expresses the classification of the upper Paleozoic rocks of Illinois as interpreted by Mr. Worthen in 1866:[3]

Coal Measures and Millstone grit	Coal Measures, 600–1,200 feet and Conglomerate.
Subcarboniferous	Chester group, 500–800 feet.
	St. Louis group, 50–200 feet.
	Keokuk group, 100–150 feet.
	Burlington limestone, 25–200 feet.
	Kinderhook group, 100–150 feet.
Devonian	Black slate, 10–60 feet.
	Devonian limestone, 10–120 feet.
	Oriskany sandstone, 40–60 feet.
Devonian and Silurian	Clear Creek limestone.

Mr. Worthen in the first report considered the "Clear Creek limestone as equivalent, in its upper part, to the base of the Devonian. The name "Chester group" is proposed by Worthen for the "Chester limestone" and the underlying "Ferruginous sandstone" of the Missouri Reports. The "Warsaw limestone" (Hall) of the Iowa Report, Mr. Worthen united with the "St. Louis limestone" of Missouri to form the "St. Louis group." He also united the "Geode bed," the "Keokuk limestone," and the underlying "Cherty beds" of the Iowa Report to constitute his "Keokuk group." The "Siliceous group" of Tennessee and Alabama he regarded as a southern extension of this same "Keokuk group" of Illinois. The author further pointed out the fact that the—

> Subcarboniferous limestone becomes arenaceous on the northeastern border of the coal field, and that all the upper members above the Kinderhook group thin out in that direction, and are replaced by the grit stones forming the lowest member of the series; and in Ohio these grit stones occupy the entire horizon from the Conglomerate to the "Black slate."[4]

The name "Burlington limestone" was adopted with substantially its original meaning as applied by Hall in the typical locality, Burlington, Iowa. It was not recognized outside the States of Iowa, Illinois, and Missouri. It is famous for the great abundance of crinoids, which are found in beautiful preservation about Burlington.

---

[1] See *Geol. Survey of Ill.*, vol. 1, p. 40.
[2] *Ibid.*, p. 61, et seq.
[3] Ibid., vol. 1, p. 26.
[4] Ibid., p. 101.

The name "Kinderhook group" was proposed by Messrs. Meek and Worthen in 1861 in the course of a discussion on the geological positions of the Goniatite beds of Rockford, Indiana.[1] Its original application was to the rocks between the top of the Black slate and the base of the Burlington limestone as seen at Kinderhook, Pike County, Illinois. In the present report Mr. Worthen further defined the group, and defended its reference to the Carboniferous.[2] He defined it as including "the Chouteau limestone, the Lithographic limestone, and the Vermicular sandstone and shales of the Missouri Report, the so-called 'Chemung rocks' of the Iowa Report, that part of the 'Waverly sandstone' of Ohio which overlies the Black slate of that region, and the 'Goniatite limestone' of Indiana."[3]

This group, the "Kinderhook," was traced into Indiana, where it is represented by grit stone and arenaceous deposits, and is regarded as the only division of the Subcarboniferous in northwestern Indiana and in northern Ohio, where it constitutes all the so-called "Waverly sandstone." The Kinderhook group of Worthen constituted the lowest member of the Carboniferous system of the upper Mississippi province.

Mr. Worthen correlated "a series of dark blue, green, or chocolate colored shales, passing locally into a black bituminous shale," of western and southern Illinois with the "Black slate" of Tennessee and other States in the interior.[4] Certain Devonian limestones were recognized immediately underlying it, and from this fact and the presence of *Lingula spatulata* he correlated it further with the Genesee slate of New York. In that part of the State it is followed by the Kinderhook group. In the northern part of the State, however, in Rock Island County, the author reported the Black slate and the Subcarboniferous limestone series absent, the Coal Measures resting unconformably upon the Devonian limestones, which were correlated with the Corniferous limestone of New York by their fossils.[5]

In the southern part of the State a sandstone was observed which Mr. Worthen identified with the Oriskany sandstone of New York. This was first observed in the neighborhood of Jonesborough, Union County, Illinois.[6]

In the second volume, published in 1866, slight changes were made in the classification and nomenclature. The introduction was by Messrs. Meek and Worthen.

The classification preferred is as follows:[7]

				Feet.
Carboniferous system	Upper	Carboniferous period.	Coal Measures, Millstone Grit	1,200
	Lower	Mountain limestone or Subcarboniferous period	Chester group	800
			St. Louis beds	200
			Keokuk group	150
			Burlington group	200
			Kinderhook group	150

[1] Am. Jour. Sci., vol. 33, p. 228.
[2] Ibid., pp. 108–118.
[3] Ibid., p. 109.
[4] Ibid., p. 119.
[5] Ibid., p. 121.
[6] Ibid., p. 124.
[7] Geol. Surv. Ill., vol. 2, p. viii.

			Feet.
Devonian system..	Hamilton period..	Genesee division ("Black slate" and grayish shale)	100
		Hamilton beds	120
	Upper Helderberg period. Corniferous and Onondaga beds		25
	Oriskany period..	Oriskany, upper bed	40
		Oriskany, lower beds or Clear Creek group	200
Silurian system.....	Lower Helderberg period.		

In this table the use of the term "Subcarboniferous" as meaning below the coal-bearing strata is clear. The recognition of the absence of upper Devonian is to be noticed. In the Oriskany the upper cherty part only of what was originally included in the "Clear Creek group" is placed in the Devonian. The lower part as it arrives at Bailey's landing, Perry County, was correlated by its fossils with the "Shaly limestone of the lower Helderberg group."[1]

The authors, after the proposal of the name "Kinderhook group," examined the rocks in Ohio and concluded that the "Waverly sandstone" or more properly "Waverly group," is of the same age, and suggested that it may be necessary to adopt the earlier name. Still they think it wise to retain the local State names until exact parallelism be established.

The third volume was published in 1868. The authors of the Geology, besides A. H. Worthen, were H. Engelmann, H. C. Freeman, and H. M. Barris. The paleontology was by Meek and Worthen. In this report "Lower Carboniferous" is substituted for "Subcarboniferous" of the earlier reports. In the volume are described a number of invertebrates from the Devonian, Kinderhook, and other deposits of Illinois, and there are descriptions of sections for several of the counties in the western part of the State.

The fourth volume was published in 1870. Bradley and Green took the place of Engelmann and Freeman. The paleontology of vertebrates was by Newberry and Worthen; of plants, by Lesquereux. "Lower Carboniferous" and "Carboniferous system" are used to cover the upper and lower divisions of the Carboniferous.

The fifth volume was published in 1873. A. H. Worthen and James Hall were the geologists, and Messrs. Meek and Worthen the paleontologists. In this report the nomenclature is "Carboniferous system" and "Lower Carboniferous system."

The sixth volume was published in 1875. The geologists were Messrs. Worthen, Broadhead, and Cox; the paleontologists, Messrs. Orestes St. John, Worthen, and Meek.

The seventh volume was published in 1883. Mr. Worthen, the geologist; paleontologists. Messrs. Worthen, St. John, and S. A. Miller. Addenda appear in this volume, written by Messrs. Wachsmuth and Barris.

I have noticed no particular change in the geological nomenclature

[1] Am. Jour. Sci., vol. 33, pp. XI-XII.

in either of the last two volumes. They are devoted to the elaboration of the details of geology in the counties and to paleontology.

Mr. Henry Englemann,[1] in 1868, described the Lower Carboniferous formations of southern Illinois as follows:

Underlying the Coal Measures in central Illinois, Iowa, and Missouri, were distinguished the following formations:

1. The Ferruginous sandstone.
2. The St. Louis limestone.
3. The Warsaw limestone.
4. The Keokuk limestone.
5. The Encrinital or Burlington limestone.

Farther south the "Kaskaskia or Chester limestone" was found between the Coal Measures and the Ferruginous sandstone; and heavy masses of sandstone ("Millstone grit") were observed next below the Coal Measures, and also beds of sandstone intercalated with the Chester limestone.

The author discovered that in the extreme southern part of Illinois this upper division of the Lower Carboniferous attains a much greater and more varied development, while the lower subdivisions seen farther north are lost or merged into one. He subdivided the series as follows:

A. Coal Measures.

B. Millstone grit, reaching a thickness of 500 feet, with a seam of coal far above the middle dividing it into Upper and Lower Millstone grit.

C. Strata corresponding to the Chester limestone and Ferruginous sandstone, and consisting of alternations of siliceous, Archimedes and Pentremital limestones, of hales, and sandstones, attaining a maximum thickness in Johnson County and adjoining counties of 1,000 feet.

The different layers of limestones and sandstones are described in detail.

D. The St. Louis limestone, with a thickness of 200 feet or more.

Some of the layers have an Oolitic structure. Underneath this are shales, siliceous slates, and some black laminated slate,[2] considered by good authorities as of the age of the Chemung group. Below these are well marked Devonian strata.

The general features of the geology of Tennessee were defined in the various reports of Gerard Troost, and some of the names which have been preserved were proposed by him.

In 1869 appeared Safford's "Geology of Tennessee," which elaborates the work begun by Mr. Troost, and presents a systematic classification

[1] Englemann, Henry: On the Lower Carboniferous system as developed in southern Illinois. St. Louis Acad. Sci., Trans., vol. 2, 1868, pp. 188–190.

[2] This paper was written later than the publication of the first Report of the Geological Survey of Illinois, in which, as is quoted on a previous page, the name "Chester group," was proposed to include the formations which had previously gone under the names "Kaskaskia limestone," "Ferruginous sandstone," and "Chester limestone."

Dr. Englemann, who was at the time of writing this paper (1868) one of the geologists on the survey of Illinois, elaborates the facts as exhibited in southern Illinois.

of the formations in unison with the correlations and nomenclature of neighboring States.

In Mr. Safford's[1] report the upper Paleozoic terrane of Tennessee is sharply defined above and below. It rests, with very slight unconformity, but with unmistakable interval, upon Upper or Lower Silurian rocks, and is capped, with more distinct interval, by the Cretaceous or later rocks. The classification proposed by the author is as follows:

10. Cretaceous.

9. Coal Measures ..... { Upper Coal Measures. / Conglomerate. / Lower Coal Measures.

8. Lower Carboniferous ..... { Mountain limestone. / Siliceous group.

7. Black shale.

Silurian—either "6. Lower Helderberg; 5. Meniscus limestone, Dyestone group; or 4. Nashville," as the case may be, etc.

The lowest member of this upper Paleozoic terrane is the "black shale," a bituminous black shale with grains or nodules of pyrite, which is widely distributed, and, whenever present, is a valuable stratigraphic bench mark. In the eastern part of the State it rests on the "Nashville, or Dyestone, or Meniscus formation;" farther west, on the opposite side of the central basin, the subjacent formation is "Meniscus, Dyestone, or Lower Helderberg." West of the Cumberland tableland it is not solely a black shale; it thins on going westward, and at its top, in a lighter colored shale, is a thin layer of argillaceous fetid concretionary bodies called "Kidneys," and taking the place of the lower layer is a stratum varying from 1 to 15 feet of dark gray fetid sandstone, containing the same *Lingula* seen in the typical black shale. This character of the formation is seen in Wayne and Hardin Counties. The author considered this to be the equivalent of the Devonian, and particularly of the Genesee shale of the Hamilton Period of New York.[2] The highest rocks seen underlying this were referred to the Lower Helderberg division of the Upper Silurian. The black shale throughout the book is spoken of under this name and not as Devonian. The black shale formation is in some places associated with a sandstone layer containing the same *Lingula*, varying from a few inches to 15 feet. (Wayne County.)[3] Above the black shale is also seen in places a layer of "kidney concretions." It is defined as "a thin layer of argillaceous, very fetid, concretionary bodies called 'kidneys.'" They are in a bluish shale and vary in size from an inch or less to 2 feet in diameter. In the more eastern sections this black shale rests on the "Nashville" (Sumner County) "Niagara or Dyestone group" (De Kalb and Maury Counties); farther west, on the "Meniscus limestone" or Helderberg (Wayne and Hardin Counties). Wherever it occurs it is overlain by the "Siliceous group," or else is the top rock. The place of unconformity is thus shown to be below the black shale formation.

[1] *Geology of* Tennessee, by James M. Safford, State geologist, Nashville, 1869.
[2] *Ibid.*, p. 157.
[3] *Ibid.*, p. 331.

The "Lower Carboniferous," or "Formation VIII," is primarily defined as "the great group of strata intervening between the black shale and the Coal Measures," with a maximum thickness of 1,200 feet.[1] This is subdivided into (8*a*) the "Siliceous group" and (8*b*) the "Mountain limestone." This, as the author remarks, "is the most useful division that can be made, so far at least as the consideration of the topographical and agricultural features of the State are concerned."

The Coal Measures are classified by the author in three divisions: (*a*) the "Lower Coal Measures," varying from a few feet to 300; (*b*) the "Conglomerate;" (*c*) the "Upper Coal Measures," from 200 to 2,000 feet thick.

It is evident that this classification is primarily a natural classification of the rock formations according to their prominent petrographic features. To take them in detail: Safford's "Siliceous group" (8*a*) embraces about the same rocks as were previously defined by Troost under the name Siliceous stratum." The name is suggested by the fact of the predominance of siliceous material in the rocks in the form of "chert, fine sandstone, silicocalcareous rock or siliceous shale." The "Siliceous group" as it appears in Middle Tennessee, is subdivided, into "a lower," the "*Protean member*," and an upper or "Lithostrontion bed." From a study of the characters distinguishing the two it is evident that the presence of the Lithostrontion in the upper member is chiefly relied upon, the lithologic characters not presenting any constant distinction, and the author states that no division is practicable in East Tennessee.[2] Two characters are mentioned as pertaining to the "Lithostrontion bed"—the fossiliferous character of the cherts and the liberation of oxide of iron in the decomposing of the cherts. The author also thinks the two members become one below Huntsville, on the anticlinals of Alabama,[3] being characterized throughout by *Lithostrontion Canadense*. He correlates the "Protean member" in general with the "Lower Carboniferous limestone below the St. Louis limestone" of the Iowa and Illinois and Missouri classification, and the "Lithostrontion bed" he correlates with the "St. Louis limestone." The "Mountain limestone" is "a heavy group of limestones and shales, the latter constituting in the aggregate about one-fourth of the mass," including a sandstone near the base which in the northern part of the State is 40 or 50 feet thick. This formation reaches its maximum thickness in the southern part of the State (720 feet), decreasing going northward until near the Kentucky line it is reduced to 400 feet.[4] The limestones are often argillaceous, sometimes oolitic, but rarely cherty. The fauna is considered equivalent to that of the Kaskaskia limestone (Hall) of the Northwestern States (=the Chester limestone of Worthen). Thus the name "Mountain limestone" is used in a restricted sense.

The author's classification is primarily a lithologic classification of the

[1] Geology of Tennessee, by James M. Safford, State geologist, Nashville, 1869, p. 338.
[2] Ibid., p. 347. [3] Ibid., p. 348. [4] Ibid., p. 352.

strata represented within the State. Above the Silurian they are as follows:

1. Black slate formation, at the base,
2. Siliceous formation, or the series of cherty limestones,
3. The Argillo-limestone formation, called the Mountain limestone,
4. The Lower Coal Measures, separated by
5. The conglomerate from the
6. Upper Coal Measures.

Fossils were reported and were used in correlating the several formations, but the subdivisions were much less finely drawn than in Illinois, Missouri, or Iowa, where fossils were more abundant in the Mississippian series.

The classification of the Lower Carboniferous formations into two groups, the "Siliceous" and the "Mountain limestone," is worthy of attention, but until the faunas are thoroughly studied this can not be considered as final. A comparison of the various faunas reported from the "Subcarboniferous," or "Lower Carboniferous" formations of the interior had already demonstrated considerable difference in the association of species in different parts of the area, but of the marine faunas the line which appears generally more sharply drawn is that between (*a*) the St. Louis (and, where present, the Warsaw,) and (*b*) the fauna next below, as the Keokuk and Burlington.

In the reports of the second survey of Iowa,[1] some modification of the classification proposed by James Hall in 1858 is seen. Mr. White reported in volume 1 the following classification:

			Feet.
Carboniferous	Coal Measures	Upper	200
		Middle	200
		Lower	200
	Subcarboniferous	St. Louis limestone	75
		Keokuk limestone	90
		Burlington limestone	190
		Kinderhook beds	175
Devonian	Hamilton	Hamilton shales and limestone	200
Silurian		Niagara limestone	

Mr. White referred all the Devonian strata of Iowa to a single formation, the Hamilton group of New York, and did not recognize any representative of either Upper Helderberg or Chemung. The Carboniferous system is present in only the two members, which he called "Subcarboniferous" and "Coal Measures." He used "Subcarboniferous group" as synonymous with the old terms "Carboniferous limestone," "Subcarboniferous limestone," and "Mountain limestone." In the subdivision of this group and its nomenclature he evidently follows the first and second Illinois reports.

Mr. F. B. Meek[2] wrote a report on the Spergen Hill fossils in 1873.

[1] Report on the Geological Survey of the State of Iowa to the Thirteenth General Assembly, for 1870, containing results of examinations, etc., made 1866, 1867, 1868, and 1869. By Charles A. White, M. D. Vol. 1, 1870.

[2] *Meek, F. B.:* Spergen Hill fossils identified among specimens from Idaho. Am. Jour. Sci., 3d ser., *vol. 5, 1873, pp. 383, 384.*

The Spergen Hill fossils found at Bloomington, Ind., at about the horizon of the Lower Carboniferous series, are miniature representatives of known larger species, belonging for the most part to the genera of Corals, Blastoidea, Brachiopoda, etc. They are crowded together in immense numbers, but finely preserved, in this locality, and a few have been found at the same horizon in Illinois, Iowa, and Missouri, but none in such numbers, or in any locality west of Missouri or Iowa, until Mr. Meek discovered hundreds of these little fossils in a small, dark-gray mass of crumbling limestone, brought by Professor Bradley from Idaho. The fossils belong to about 17 species of the same genera found at Spergen Hill, and of the species about one-half were undistinguishable from the Spergen Hill forms.

In the first annual report of the Survey of Minnesota[1] a chart[2] is presented with some modifications in the classification and correlations of the Mississippian series.

The Carboniferous system is represented on the chart, although nothing representing it is recorded for Minnesota, and is divided into the following groups:

Permian.
Coal Measure.
Carboniferous conglomerate.
Subcarboniferous.

The Subcarboniferous group is made up as follows for North America:

Subcarboniferous.....	Mississippi formation	Chester limestone.
		St. Louis limestone.
		Keokuk limestone.
		Burlington limestone.
	Marshall formation	Marshall sandstone.

The "Mississippi formation" is the equivalent of the "Mountain limestone" of Europe and Tennessee.

The "Marshall formation" is the equivalent of the "Kinderhook" of Iowa and Illinois and of the "Old Red sandstone" of Europe.

The Devonian system is made up as follows:

System.	Groups.	Formations.	Strata of North America.
Devonian ..	Hamilton	Hamilton....	Huron shale.
			Hamilton limestone.
	Upper Helderberg	Corniferous..	Corniferous limestone.
			Onondaga limestone.
		Oriskany....	Schoharie grit.
			Cauda-galli grit.
			Oriskany sandstone.

The usage of "Mississippi" as a name for the limestones of the Sub-

[1] The Geological and Natural History Survey of Minnesota, by N. H. Winchell, State Geologist, 1873.

[2] Chart of geological nomenclature, intended to express the relation of Minnesota to the great geological series of the earth, and the probable equivalency of some of the names the formations have received in the various States and in Europe, opp., p. 40.

carboniferous is according to the proposal of Alexander Winchell in 1870, (see ante, p. 135). The "Marshall formation" is also according to the classification proposed by Alexander Winchell. As the whole Carboniferous and all of the Devonian except beds with a very meager fauna are wanting in Minnesota and the author does not explain the reasons for his departures from ordinary usage, it is useless to make further comment.

In 1873 two reports[1] were published upon the geology of Missouri, under the directorship of Mr. Raphael Pumpelly.

In the first of these reports the work consists of material previously unpublished, mainly details of county surveys made before 1861, the maps and charts having been struck off prior to 1861. Pages 1 to 110 are by G. C. Broadhead, 111 to 188 by F. B. Meek, and 189 to 323 by B. F. Shumard. The nomenclature is substantially the same as that of the first and second reports of G. C. Swallow, 1855.

In Mr. Shumard's report on Sainte Genevieve County,[2] a classification is given which deserves attention.

Opposite page 292 is an engraved chart entitled "Vertical section of strata observed in Sainte Genevieve County, by B. F. Shumard."

The part of this chart referring to the present discussion is as follows:

				Feet.
Carboniferous system.		*e.* Coal Measures.	Hard siliceous limestone	10
			Dark purple and drab shale	25–40
			Micaceous sandstone	30
	Archimedes group.	*h.*	Archimedes limestone or Kaskaskia limestone	200
		f.	Sandstone	80
		h'.	Archimedes limestone	50
		g.	St. Louis limestone	150
		h''.	Oolitic limestone	20
			Archimedes limestone or Warsaw limestone	80–100
		i. Encrinital limestone		200–300
Devonian.	Chemung group.	*j.*	Chouteau limestone	90
		k.	Vermicular sandstone and shale	25–30
		l.	Sandstone	25
		p.	Hamilton	25
		m.	Oriskany	

As explained in the text, the upper Archimedes limestone (*h*) is the equivalent of Hall's "Kaskaskia limestone;" the "Sandstone" (*f*) is the "Ferruginous sandstone" of the earlier reports.

[1] Reports on the geological survey of the State of Missouri, 1855 1871, by G. C. Broadhead, F. B. Meek, and B. F. Shumard, published by authority of the legislature, under the direction of the Bureau of Geology and Mines, pp. 323, and index, 1873.

Preliminary report on the iron ores and coal fields from the field work of 1872. Part I, pp. 1–218, part II, pp. 1–402, bound in one volume. Raphael Pumpelly, director. 1873.

Part II. Geology of Northwestern Missouri, by G. C. Broadhead, and of Lincoln County, by Wm. B. Potter.

[2] *Pages 292–293.*

The name "Ste. Genevieve limestone" is proposed for the second Archimedes limestone (*h'*) of the table (p. 293).

The "third Archimedes limestone" (*h''*) is the "second Archimedes" or "Warsaw limestone" of Hall's section (p. 294).

The classification of the formations between the top of the Encrinital limestone and the base of the Coal Measures into a distinct group under the name "Archimedes group" is worthy of particular notice. Although the author made little account of it, and as far as I have ascertained no further notice has been taken of it, recent studies have convinced me that the primary subdivision of the Mississippian series, based upon affinity and difference in the faunas, calls for a line of demarcation at the place here indicated. The faunas of the Chester, St. Louis, and most of those referred to the Warsaw formations are paleontologically more closely allied than they are to the faunas of the Keokuk and Burlington—i. e., the Encrinital of the Missouri geologists—and considering the variations in the lithologic characters of these formations in different parts of the Mississippi province I believe the division of the Mississippian series into three groups defined upon paleontologic grounds will greatly facilitate the understanding of the relations of the various formations, whose differentiation hitherto has been made upon lithologic character. This will avoid the necessity, as the finer details of the geology are developed, of forced correlation with already named formations, which is the only alternative to proposing new names where the local stratigraphy is dissimilar to that of the typical section.

For the uppermost of these groups, which is that called Archimedes group by Dr. Shumard, I would propose the name Genevieve group, as it was first defined in the county of Ste. Genevieve, by Shumard, and along the eastern border of this county is well represented, as is shown in Shumard's Report.[1]

To apply this classification I propose the following scheme, which expresses the subdivisions into groups indicated by the fossil faunas of the Mississippian series:

Mississippian series.	Genevieve group...	Chester. St. Louis. Warsaw (in part).
	Osage group.....	Keokuk. Burlington.
	Chouteau group....	Chouteau limestone and the "Vermicular" and "Lithographic" formations as proposed by G. C. Broadhead in the following report:

In 1874 Mr. G. C. Broadhead published a detailed report of surveys made by him as State geologist during the years 1873 and 1874.[2]

[1] Geol. Surv. Missouri, 1855–'71, pp. 292–294.

[2] Report of the Geological Survey of the State of Missouri, including field work of 1873–'74, with 91 illustrations and an atlas, by Garland C. Broadhead, State Geologist. Printed by the authority and under the direction of the Bureau of Geology and Mines. Jefferson City, 1874 (pp. 734 and index).

The classification he proposed is slightly different from that given in Mr. Worthen's first report of the Geological Survey of Illinois (1866).[1] It is as follows:

- Carboniferous system.
  - Upper Carboniferous or Coal Measures.
    - Upper coal.
    - Middle coal.
    - Lower coal.
    - Clear Creek sandstone and lower coal.
  - Lower Carboniferous
    - Chester group ..
      - Chester limestone and Ferruginous sandstone.
    - St. Louis group.
      - St. Louis limestone and Warsaw limestone.
    - Keokuk group..
      - Encrinital and Burlington group.
    - Chouteau group.
      - Chouteau limestone.
      - Vermicular sandstone and shale.
      - Lithographic limestone.
- Devonian system
  - Hamilton.
  - Onondaga.
- Upper Silurian
  - Oriskany.

In the use of Chester, St. Louis, and Keokuk groups he follows Worthen (1866).

He proposes the name "Chouteau group" to take the place of the "Chemung group" of Swallow's Report of 1855,[2] which included—

1. Chouteau limestone, 100 feet.
2. Vermicular sandstone and shale, 75 feet.
3. Lithographic limestone, 55 feet.

"The Chouteau limestone," he reported, "in the upper part is a coarse gray limestone resembling the lower beds of the Encrinital limestone. In fact it is a bed of passage, as it often contains fossils common to both." "At the base of the group in northeast Missouri a few feet of black slate are occasionally seen." The volume adds very little to the development of the correlations of this region. The "Chouteau group" is a very appropriate addition to the nomenclature. The classification of these formations as a group had been early recognized, but the erroneous correlation fixed upon it a name which no one had heretofore replaced. The "Kinderhook group" of Meek and Worthen is synonymous from a stratigraphic point of view, but the fauna and lithology of the Chouteau group on the western margin of the Ozark uplift present sufficient differences to make the retention of the name desirable.

As we conclude this review of the development of the correlation and classification of the Mississippian series, the problems appear simple, but they were complex and confusing to those who elaborated them.

[1] Report of the Geological Survey of the State of Missouri, including field-work of 1873–'74, with *91 illustrations* and an atlas, by Garland C. Broadhead, State Geologist. Printed by the authority and *under the direction of the* Bureau of Geology and Mines. Jefferson City, 1874, pp. 20, 24.

[2] *Ibid., p. 26.*

In New York State, which had given the most perfect section of upper Paleozoic formations, there appeared a complete series of deposits distinguished by easily recognized differences in their lithologic characters and in the fossils. The Coal Measures in Pennsylvania formed an easily recognized datum above, and below the Devonian the sections led by regular stages downward.

As the eastern geologists went westward they attempted to correlate the deposits discovered with the familiar standards of the Appalachian province, the New York and Pennsylvania systems. The geologists who began their investigations in the Mississippi Valley and westward correlated the formations with European standards, finding little to help them in the eastern sections, and in the finer subdivisions classified them independently, as the New York geologists had already done with their strata.

On comparing notes, the geologists found that there were unmistakable differences in the rocks which occupied the same general intervals, which were more extreme the more distant the contrasted sections were from each other, and they assumed (a conclusion which was natural at that stage of progress in the science) that like differences might be allowed for the faunas. This error was fatal and delayed for years the acceptance of the correct interpretation which those who depended upon evidence of fossils alone made in the early part of the discussion.

With the recognized variation in the composition of the strata, a black shale which was present in a great number of the sections across the country, and certainly below the Coal Measures and above Silurian rocks, was seized upon as a common horizon by means of which the sections of separate States might be tied together. The problem regarding the black shale consisted in the fact that in the standard sections of New York there were two black shales, the Marcellus and Genesee, with the rich Hamilton fauna between them. When correlations were followed across the States it was seen that no black shale appeared in the northern part of the Mississippi Valley, but a Hamilton fauna was found, and in the more southern sections little or no trace of Hamilton faunas, but a single black shale.

In the solution of this problem a study of the fossils alone finally brought out the truth.

A third problem came up, particularly concerning the sections of Ohio, Michigan, and western Pennsylvania. With slight differences in the characters of the deposits, on passing westward from the typical upper Devonian of New York, there appear slight changes in the character of the faunas. The question was, Is this a geographical modification, or is it a change coordinate with sequence of time? For the Chemung faunas do not extend westward under the Waverly, nor do the Waverly faunas extend eastward over the Chemung. This problem is being gradually settled by a minute study of the fossils, and the discovery of

the characteristics of species coordinate with temporal sequence. It is the light which evolution has thrown upon the history of organisms that is doing more to clear up the correlations involved than all the minute stratigraphy which has been applied to their interpretation. The true position of the fauna in the chronologic scale was, moreover, first clearly discerned in the Mississippian series by Meek and Worthen, who, in 1861, proposed the name "Kinderhook group" for the erroneously identified Chemung rocks of Iowa, Illinois, and Missouri. The fundamental correlation involved had been announced as early as 1847 by M. de Verneuil, but Mr. Meek was the first American palæontologist to insist on the correctness of the interpretation, and to carry it out in the classification of the rocks of the country.

Another problem which chiefly concerns the various members of the Mississippian series is that regarding the subdivision and correlation of the parts of the series as exhibited in separate sections.

So far little advance has been made beyond the interpretation given by Dr. D. D. Owen in 1852, chiefly on structural grounds.

In the geological reports of Iowa and Illinois, and in separate publications elsewhere, the faunas have been largely described, but the materials have not been studied with sufficient attention to their biological character to determine the true relations of the faunas to each other and to chronologic sequence. The evidence now in hand enables us to point out where to draw the paleontologic lines to indicate the three general faunas above named, 1, Chouteau; 2, Osage group; and 3, Genevieve group; but the full content of each fauna and the precise points at which the stratigraphic lines should be drawn in local sections is not in all cases clear.

CHAPTER VIII.

THE WAVERLY PROBLEM: THE HISTORY OF THE DISCUSSION CONCERNING THE CORRELATION OF THE WAVERLY, MARSHALL, GONIATITE LIMESTONE, KINDERHOOK AND CHOUTEAU FORMATIONS.

In the second stage of development in the history of geologic correlations, American geologists did not rely solely upon fossils, but prominent stratigraphic units of each new province surveyed were identified, partly by their petrographic, partly by their paleontologic characters; and local and independent classifications and nomenclatures were constructed, using these stratigraphic units as datum levels. Thus the Coal Measures, with actual coal beds, formed the most conspicuous datum plane for the correlation of the interior; then the limestones below were correlated with the Carboniferous limestones of England. Going still finer, the Black shales (often called "black slates") assumed a prominent rôle in determining the division line between the Carboniferous and Devonian.

The Coal Measure Conglomerates have also played a prominent part in marking the base of the Coal Measures, although in actual age, as represented by the evolutional history of organisms, I am inclined to believe that in different parts of the country the whole length of the Carboniferous limestone period transpired between the times when the lowest Coal Measures of the several regions began, and that, therefore, Conglomerates which mark the elevation preceding such Coal Measures vary greatly in age. The Oriskany sandstone played a similar part in the more eastern sections. The Catskill sandstone, as the supposed equivalent of the Old Red sandstone, formed a conspicuous landmark and division plane between Devonian and Carboniferous in the northern Appalachian province.

The influence of the belief in the continuity of such stratigraphic units was, and is still, one of the stumbling-blocks in the way of a correct interpretation of the relation between the Waverly formations of Ohio, and the more eastern strata of New York and Pennsylvania and those of Indiana and the Mississippi province farther west.

In the more minute application of correlation methods the same influence predominates. In attempting to classify the formations across State boundaries, the prevailing custom has been in the case of each prominent limestone or sandstone to seek the corresponding limestone

or sandstone in the nearest State already surveyed with which to correlate it. This custom is satisfactory in some cases, and in others it fails because of the inconstancy of the conditions of sedimentation; and, using the criterion of fossils, whenever considerable distance intervenes, there is clear indication of difference in the time of beginning and ending of a formation which in its general characters may indicate equivalency of age. Doubtless the same principles of correlation have been applied in the interpretation of the formations below and also of those above the Upper Paleozoic. Of these others may speak. This custom having prevailed during the last fifty years, it is in the discussion regarding the correlation of the dominant stratigraphic units that we find best expressed the methods and usages employed.

During the last half century a large number of papers have been written, having as a common theme some form of the problem regarding the demarkation between the Devonian and Carboniferous systems. These papers and discussions have gathered mainly about the interpretation, taxonomic value and position of the Waverly group, the Kinderhook group, the Marshall group, the Black shale and Goniatite limestone formations, the Catskill, the "Old Red sandstone," and the variously named Conglomerates.

The determination of the demarkation between the Devonian and Carboniferous systems presented itself under different names to each of the State surveys of the States in which the transition is seen. In New York and the States of the Appalachian Basin it appeared in the discussion regarding the Catskill formation and the Conglomerates; in Ohio it was regarding the Waverly formations; in Michigan it was the Marshall group; in Indiana it was about the Goniatite limestone and the Black shale; in Kentucky and Tennessee it was the Black shale and the Siliceous group; in Illinois it was the Kinderhook group; in Iowa and Missouri it appeared first under the name "Chemung group," later as Kinderhook group in Iowa and as Chouteau group in Missouri. In each of these various States the difficulties were similar: the absence of any satisfactory definite standards of delimitation, either in stratigraphic or paleontologic terms, between the Devonian and Carboniferous systems.

In New York State the highest pure marine fauna in the Chemung is equivalent in a general way to the upper Devonian fauna of North Devonshire. But some of the species recorded in the upper Devonian of Europe are more conspicuous in formations stratigraphically above the Chemung horizon in America. Again, the Catskill formations in New York, containing estuarian faunas, carry also plants, which on the one hand indicate close affinities with the Carboniferous, but are stratigraphically well below true Carboniferous deposits of the Appalachian province.

When, however, New York series are taken as the standard, the *terminal part of the* Devonian presents no parallel, either stratigraphically

or paleontologically, even in Ohio; still less in the States farther west. In each case it is a comparison of allied but dissimilar series.

The Catskill and Conglomerate problems are discussed in a former chapter. Some of the problems associated with the Kinderhook and Chouteau groups have been considered in the chapter on the Mississippian series. In the present chapter I propose to consider the problems associated with the correlation of the Waverly, the Marshall, the "Black shale" and the Goniatite limestone formations, and secondarily the Kinderhook and Chouteau. In the first chapter is discussed the development of opinions and nomenclature concerning these formations up to 1843, and in the chapter on the general correlations of the formations westward from New York to the Mississippi Valley, this development is traced onward to about the year 1851.

The succession of strata in Michigan as published in 1838–'41, arranged in descending order, as compiled from Dr. Houghton's Annual Reports, is as follows:[1]

XXXI. Recent Alluvium.
XXX. Ancient Alluvium.
XXIX. Erratic Block and Diluvium.
XXVIII. Tertiary Clays.
XXVII. Brown or gray sandstone.
XXVI. Argillaceous iron ore.
XXV. Coal strata.
XXIV. Red or variegated sandstone.
XXIII. Gray or yellow sandstone.
XXII. Shales and coal, Lower Coal Measures.
XXI. Blue compact slaty sandstone.
XX. Gray limestone or upper lime rock.
XIX. Fossiliferous ferruginous sandstone.
XVIII. Kidney iron formation.[2]
XVII. Sandstone of Point aux Barques.
XVI. Clay slates and flags of Lake Huron.
XV. Point au Grès and Manistee limestone.
XIV. Soft, coarse-grained sandstone.
XIII. Black bituminous, aluminous slate.
XII. Limestone of Lake Erie.
D. Corniferous limestone; C. Thunder Bay and Little Traverse Bay limestone (*f–a*); B. Black bituminous limestone; A. Blue limestone.
XI. Mackinac limestone.
X. Polypiferous portion of Upper Limerock.
IX. Pentamerus portion of Upper Limerock.
VIII. Lower limerock and shale.
VII. Sandy limerock.
VI. Upper gray sandstone.
V. Lower or red sandstone and shale.
IV. Mixed conglomerate and sandstone.
III. Conglomerate.
II. Metamorphic rock.
I. Primary rocks.

[1] First Biennial Report of Progress of the Geological Survey of Michigan, etc., Lansing, 1861, pp. 12, 13, 14, 15.

[2] In this classification No. XVIII is made the lowest bed of the Carboniferous.

In 1851 Charles Whittlesey[1] gave an exhibit of the strata in New York, Ohio, and Kentucky, reckoning from the Conglomerate downward to the "Cliff limestone:"

NEW YORK (after Hall). Chautauqua County.

Classified by fossils.

1. Old Red sandstone, very thin.
2. Chemung group, 1,200 to 1,500 feet.
3. Portage group, 1,000 feet.
4. Genesee slate, 23 to 150 feet.[2]
5. Tully limestone.
6. Hamilton group.
7. Marcellus shale.
8. Corniferous limestone.
9. Onondaga limestone.

OHIO. Chagrin Falls, 18 miles east of Cleveland.

Classified by external characters.

Conglomerate.

1. Ash-colored shale, 110 feet.
2. Thick bedded argillaceous sandstone, 13 feet.
3. Black shale, 13 feet.
4. Grindstone grit, 38 feet.[2]
5. Fine-grained sandstone, thin and thick bedded ("Waverly"), with red, blue, and green shales interstratified—flags and ripple marks—strips of ironstone and iron rust with fossils. Lower part—"black slate" of Ohio Reports: thickness to Cliff limestone probably 400 feet. (This embraces 3, 4, 5, 6, and 7 of the New York column.)
6. Cliff limestone.

KENTUCKY. Falls of Ohio, by Dr. Yandell and Shumard.

Arranged by fossils.

1. Carboniferous limestone (Mammoth Cave).
2. Button Mould Knobs.
3. Bituminous black slate, 101 feet; in Tennessee (Owen and Shumard), 8 to 51 feet.
4. Encrinital beds, 8 feet.
5. Water-lime beds, 12 feet.
6. Shell beds, 16 feet.
7. Coralline beds[3] (upper and lower), 40 feet.
8. Catenipora beds, = "Niagara."
9. Pentamerus beds, "Blue limestone," "Clinton," "Carodoc."

According to Hall in the New York Reports, No. 5 of the Ohio section is the equivalent of the Chemung, Portage, Hamilton, and Marcellus. The author suggested the name "*Protean group*"[4] for rocks in

[1] Whittlesey, Charles. On the equivalency of the rocks of northeastern Ohio, and the Portage, Chemung, and Hamilton rocks of New York. Am. Assoc., Proc., vol. 5, 1851, pp. 207–221.

[2] No. 4 is seen at Euclid, Newburg, Independence, etc.

[3] T. M. Verneuil placed the division point separating the Silurian and Devonian between the upper and lower Coralline beds. (See Ibid., p. 215.)

[4] The name "Protean group" had been already used by L. Vanuxem for a series of rocks at the base of the Upper Silurian in New York in 1838. (See New York Geological Survey, second Ann. Rept., p. 285.) This was afterward restricted to the Saliferous group and the name abandoned. Fourth Ann. Rept., pp. 53 and 374, and Final Report on Geology, Third district, pp. 79 and 90. The name "*Protean member*" was afterward proposed by J. M. Safford for the lower part of the Siliceous group *of Tennessee.* (See ante, p. 165.)

Ohio occupying the interval between the "Grit" No. 4 and the "Cliff limestone" No. 6.

In the same year J. W. Foster reported the absence in Ohio of the representative of the conglomerates of New York State. The "Cliff limestone" he thought should be divided on biologic grounds. The sandstone formerly known as the "Waverly" should for like reasons be divided into three parts. The fossils have more Carboniferous than Devonian affinities.

The rocks of the Ohio coal field consist of sandstones, shales, limestones, seams of coal, and buhrstone. The limestones and sometimes the shales contain exclusively marine faunas, while the sandstones contain a Carboniferous flora. The alternations of marine and terrestrial remains were noticed in a vertical distance of 700 feet. The faunas and floras contained in each formation were described in detail.[1]

In 1862 James Hall[2] began to see the incorrectness of his correlation of the Waverly group and wrote:

> The Waverly sandstone group of the Ohio Reports, at one time regarded as entirely equivalent to the Portage and Chemung groups, may in its upper members constitute a distinct group, though we do not yet know any line of demarkation between them.

From 1862 to 1870 Alexander Winchell wrote several papers bearing upon the correlation of the Marshall group of Michigan. The fossils in this group proved to be closely related to those of the Waverly fauna, and thus the problems of the Marshall group of Michigan became intimately associated with those of the Waverly group of Ohio. In 1862 he briefly described the rocks of this group in lower Michigan, and their fauna.[3]

The following is a synoptical view of the strata described:

	Feet.
Carboniferous limestone	66
Michigan Salt group	184
Napoleon group	123
Marshall group	173
Huron group	210
Hamilton group	55

The rocks chiefly interesting him in this paper were a series of fine, friable, ferruginous sandstones not over 300 feet in thickness, whose upper portion, more grayish, firmly cemented, and homogeneous than the lower, is remarkably destitute of organic remains and is separated from the lower by 15 feet or more of shale containing a large amount of ferruginous matter. The lower portion of the sandstone is rich in fossil remains belonging to the genera *Goniatites*, *Nautilus*, *Orthoceras*, *Bellerophon*, *Nucula*, *Solen*, *Myalina*, *Chonetes*, etc. The upper

[1] On the alternations of marine and terrestrial organic remains in the Carboniferous series of Ohio. By J. W. Foster. Am. Assoc., Proc., vol. 6, pp. 301–304.

[2] "On the Catskill group of New York." By James Hall. Canadian Naturalist and Jour. of Science, new series, vol. 7, 1862, p. 381.

[3] Notice of the rocks lying between the Carboniferous limestone of the lower peninsula of Michigan and the limestones of the Hamilton group, with descriptions of some cephalopods supposed to be new to science. By Alexander Winchell. Am. Jour. Sci., vol. 33, 1862, pp. 352–366.

sandstones were called the "*Napoleon group*" and the lower the "*Marshall group.*" Mr. Winchell traced the course of the outcrops of these groups to the northeast and west and spoke of their being overlaid by the *Michigan Salt group* at Grand Rapids and vicinity and underlaid in the southwestern counties by a considerable thickness of argillaceous strata. In Huron County the "*Huron group*" of gritstone, green shales, and bituminous shales is found beneath the *Marshall sandstone*, and farther north the Hamilton limestones precede this group.

The descriptions of supposed new Cephalopods comprise ten species of Orthoceras, seven of Nautilus, one of Cyrtoceras, and eight of Goniatites.

In a paper[1] published in 1863 Mr. Winchell stated his conviction that a comparison establishes "fully the equivalency of the Chemung, Marshall, Ohio [i. e., Waverly], Rockford [i. e., Goniatite limestone], Burlington [i. e., Kinderhook], and Chouteau strata."[2]

Further investigation modified this conviction, as we shall see beyond.

In 1864 appeared another paper.[3] This was devoted to a description of certain western rocks near the line between the Devonian and Carboniferous systems and their contained faunas. "The paper shows an extended net-work of identification among the fossils from States west of Pennsylvania." The author identifies also "four western species with those in the supposed Carboniferous conglomerate of western New York," two of which species are regarded as being at the top of Chemung rocks of western New York. He inclined to the view that since there appears no close resemblance between the Chemung of New York and western rocks, the "Carboniferous conglomerate" of western New York may be the eastern prolongation of the western sandstones and shales, at least of the fossiliferous portions of them, and that the Chemung of New York must be classed with the Devonian rocks. "Ninety-four species are described in this paper, of which thirty-six are described as new species, and two are made the types of new genera." This brief outline is followed by descriptions of the species.

The view that the so-called "Chemung" of the States west of New York should be correlated with the "Carboniferous conglomerate" system was expressed by Meek and Worthen in 1861.[4]

In 1870 Winchell completed his studies of the correlation of the Marshall group,[5] and published an elaborate memoir upon the subject. In the appendix are cited ninety papers on the geology of the rocks under consideration. He opened the paper by a reference to the "controversy which has long existed in reference to the age and equivalents of the strata lying between the Corniferous limestone and the limestone of the

[1] Winchell, Alexander, on the identification of the Catskill Red Sandstone group with the Chemung. Am. Jour. Sci., 2d ser., vol. 35, 1863, pp. 61–62.

[2] Ibid., p. 62.

[3] Descriptions of new species of fossils from the Marshall group of Michigan and its supposed equivalent in other States, etc., by Alexander Winchell, Phil. Acad. Sci. Proc., vol. 17, 1865, pp. 109–133.

[4] Am. Jour. Sci., vol. 32, 1861, pp. 167–177, 288.

[5] The Marshall group: A Memoir on its geological position, characters, and equivalencies in the *United States.* *Proc.* Am. Phil. Soc., vol. 11, 1869, pp. 57–83, and vol. 12, 1870, pp. 385–418.

Lower Carboniferous system."[1] He next gave a brief synopsis of opinions under the heading of "History of discovery and opinions," beginning with Hildreth's paper, 1836,[2] and citing the views of the chief contributors to the discussion up to 1869. Then follows a tabulation of the rock sections, as then interpreted, in the several States, including the corresponding sections of the States of New York, Michigan, Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, and Tennessee. He then proceeded to discuss "the parallelism of the formations on purely structural and lithological grounds," and remarked that "the identity of the black shale can not now be mistaken." He referred to its demonstrated position above the Hamilton group in Michigan, Kentucky, and Ohio, and below the Rockford Goniatite beds in Indiana. He thought it was unrepresented in Missouri. In Michigan it may be the lower part of his Huron group, and in New York he confined the typical equivalent of the black shale to the Genesee shale on paleontologic grounds.

The Carboniferous conglomerate was next taken as marking "a superior horizon which can not ordinarily be mistaken." The Parma conglomerate of Michigan the author considered as "stratigraphically equivalent to the carboniferous conglomerate." Lithologically he found no means of distinguishing the coal conglomerate of Ohio from the Chemung and Catskill conglomerates of New York. On paleontologic grounds, however, he separated the "Chemung" and Catskill conglomerates, which he made equivalent to the "Marshall group" of Michigan, from the "Parma conglomerate," which he placed higher in the scale above the carboniferous limestones of the interior; and after discussing the fossils underlying or associated with the conglomerates, he said:

"For these reasons I shall, for the present, regard the three conglomerates[3] in western New York, with the associated strata, as belonging together in the horizon of the Catskill group."

Later investigations, particularly those of the Second Pennsylvania Survey, have thrown clearer light on the relations of these several conglomerates.[4]

The third conspicuous formation which Winchell sought to correlate was the "Carboniferous limestone series" of the Mississippi Valley. In a foot-note[5] the author proposed the name "Mississippi limestone series or Mississippi group" for the "Carboniferous limestones of the United States, which are so largely developed in the valley of the Mississippi." My adaptation of this name and proposal of the name

[1] The Marshall group: A Memoir on its geological position, characters, and equivalencies in the United States. Proc. Am. Phil. Soc., vol. 11, 1869, p. 57.

[2] Am. Jour. Sci., vol. 29, 1836, pp. 133–136.

[3] Viz, the "Chemung conglomerate," the "Catskill conglomerate," and the so-called "Carboniferous conglomerate," near Panama.

[4] See Second Pennsylvania Survey Reports III, by J. F. Carll, 1880, and Report R, by C. A. Ashburner, 1880.

[5] Proc. Am. Phil. Soc., vol. 11, p. 78.

"Mississippian series" for the formations grouped under the names Subcarboniferous or Lower Carboniferous are given in a previous chapter.

This "Mississippi limestone series" of Winchell includes the rocks in the Mississippi Valley from the "Burlington" up to the "Kaskaskia" of Iowa, and in his usage it does not include the "Kinderhook" or "Waverly." But to be of practical use the series should extend from the base of the Carboniferous, i. e., including the "Goniatite beds," the "Chouteau series," the "Kinderhook," the "Marshall," the "Waverly," upward to where the marine fauna ceases at the approach of the conglomerates or similar deposits heralding the appearance of coal.

In discussing this group, Winchell only identified, with little argument, the "Carboniferous limestone" of Michigan, the "Knobstones" of Indiana and Kentucky, and the "Siliceous group" of Tennessee, with the "Carboniferous limestone" of the Mississippi Valley, not including here, however, the formation next to be considered.

The rocks between the "black shale" and the "Mississippi limestone" above presented greater difficulties, because of the radical lithologic differences of the various outcrops representing them. The several formations are the "Waverly" and "Gritstone" series of Ohio, the Chemung and Portage groups of New York, the "Marshall sandstones" of Michigan, the "Yellow sandstones," called in the earlier report "Chemung group," of Iowa, the "Rockford limestones" of Illinois, and the "Chouteau limestones, Vernicular sandstone and shale, the Lithographic limestone" of Missouri.

The general equivalency between the Waverly and Gritstone series of Ohio and the Portage and Chemung of New York had been asserted by James Hall, and, following his authority, had been the usage of geologists for years. From this position Winchell both departed and advanced. In Michigan he recognized below the Marshall sandstones, and above what he regarded the equivalent of the Genesee shale of New York, some 500 or 600 feet of argillaceous rocks, more arenaceous and flaggy to the north. These, which he called the "Huron group," he considered as the equivalent of the Portage and Chemung of western New York.

In Ohio, below the Waverly series, he found the extension of his Huron group [what is now called the "Erie shales"], equivalent to the Portage and Chemung of New York. On similar grounds, which are lithologic and stratigraphic, he identified the argillaceous beds above the black shale in Kentucky with his Huron group. He also referred to a similar horizon the "bluish, slightly micaceous sandstones of the yellow sandstone series of Iowa, the blue shales below the lithographic limestones of Missouri, and possibly the Illinois shales doubtfully referred to the Genesee by Prof. Worthen;" and having thus, on physical grounds, found what he thought to be equivalent formations to represent the Chemung and Portage of New York, he presented a lengthy argument for regarding the Waverly series of Ohio and the

Marshall group of Michigan on paleontologic grounds, the equivalents of the Catskill rocks of New York.

In the paleontological part of the paper is given a catalogue of the known fossils of the Marshall group and its supposed equivalents in the United States, with references to the place of publication of the descriptions of the species. Four hundred and sixteen species are enumerated. No attempt is made to determine or eliminate synonyms. The distribution of the species by States is indicated. As the author takes up his argument he first speaks of the fauna of the Huron group, and concludes from a comparison of the species that it is equivalent to "the Portage and Chemung groups, or to some portion of them," and then proceeds to determine whether the overlying Marshall group should be included with the Huron shales as equivalent to the upper part of the Portage-Chemung of New York. His first argument for equivalency was that furnished by the lists of species identified in two or more States. By this means he correlated—

(1) The Marshall group of Michigan with (2) the Gritstone and Waverly down to the Chocolate shales of Ohio; (3) the Goniatite limestone of southern Indiana and its equivalent sandstone in northern Indiana; (4) the Kinderhook group of Illinois; (5) the yellow sandstone series of Iowa, at least down to the bluish shales; (6) the series known in Missouri as the Chonteau limestones, the Vermicular sandstone and shales, and the lithographic limestones, and (7) the Silico-bituminous shales at the base of the Siliceous group of Tennessee.

These correlations had been practically demonstrated for all except the Marshall group by previous writers.

A long discussion of species then follows, to show that the species contained in these formations have "a Carboniferous aspect," a fact which M. de Verneuil had long before pointed out upon his first glance at the species then known of the Ohio, Indiana, Illinois, Iowa, and Missouri localities.

The next section announces that "the fauna of the Chemung group presents a Devonian aspect." This fact had been recognized for thirty years, and the Chemung of New York had been the recognized typical upper Devonian for all correlations in North America.

Section VI proposes the question "Can the Marshall and Chemung be synchronized?" Elaborate citations of principles of paleontologic science are made and prolonged argument to prove that this is not reasonable, and to reach the conclusion that the Chemung must remain "within the limits of the Devonian system, where it has been placed by the nearly unanimous judgment of paleontologists," and that "the Marshall group must be admitted within the boundaries of the Carboniferous system according to the present nearly unanimous judgment of western geologists."

The one point which is the gist of the whole argument is made in the last section, headed "Parallelism of the Catskill and Marshall." The author's theory is that the Catskill group of eastern New York instead of thinning out or disappearing by lack of sediments in western New

York is absent in consequence of subsequent denudation; that the "Old Red" is not necessarily all Devonian in age; that in the Marshall are some species which are considered as "having near analogues in the Old Red of Scotland;" that the Catskill, although identified as the equivalent of the Old Red sandstone of Scotland and Wales, is younger than that part of the Devonian represented in New York by the Chemung and its equivalents in Europe, and as the Marshall has been shown to be not the equivalent of the Chemung in New York, it must be, the author argued, the representative of the Catskill.

At the close a table of geological equivalents is given. The part of it of chief value here is that expressing the author's interpretation of the equivalents of the Marshall group of Michigan, which consists of the following, immediately overlying the Huron group, in ascending order:

(1) Huron gritstones, bluish or greenish gray, fine grained, regularly bedded, 15 feet.
(2) Marshall sandstone, reddish, yellowish, olive, obliquely laminated, highly ferruginous; the iron often a rudely concentric, concretionary arrangement; in places calcareous, highly fossiliferous, 160 feet.
(3) Napoleon sandstone, pale buff, often conglomeratic, obliquely laminated, thick bedded, 123 feet.

Followed above by the Michigan salt group.

According to the table the equivalents to these are, in New York, upper part of Catskill group, including "Carboniferous conglomerate" and "Chemung conglomerate;" in Ohio, "Waverly series, in part" (the "Chocolate shale series" and the "base of the Waverly series" are correlated with the Chemung and Portage of New York); in Indiana, the "Rockford limestone" and "Williamsport gritstone;" in Illinois, the "Kinderhook group;" in Iowa, the "Yellow sandstone series;" in Missouri, the "Chouteau limestone," "Vermicular sandstone," and shales, and "Lithographic limestone;" in Tennessee, part of the "Siliceous group" and the "Siliceous shales," and in Europe the "Old Red sandstone" of Scotland, "Yellow sandstone" of Ireland, and the "Westphalian schists."

In 1871 appeared the Report of Progress of the Geological Survey of Ohio.[1]

Two of the chapters have matter of interest in the present discussion: One by Mr. E. B. Andrews,[2]; a second by Mr. M. C. Read.[3]

The formations discussed in Mr. Andrews's article are the "Ohio black shale" or "Huron shale," the "Waverly sandstone," the "Maxville limestone," the "Conglomerate" of the Coal Measures, and the Coal Measures.

The Waverly sandstone is divided into three parts. The middle is coarse and often a conglomerate; the division above, a fine-grained sandstone, and that below sandstones and shales, with interstratified

[1] Geol. Survey Ohio, Rep. Progress in 1870; Columbus, 1871.
[2] Report of Labors in the Second Geological District during the year 1870 in Coal Measure district, pp. 55-251.
[3] *Sketches of the Geology of* Geauga and Holmes Counties, pp. 463-484.

sandy shales. The fine-grained sandstone lying above the Waverly conglomerate was first investigated in the vicinity of Logan, Hocking County, and thence received the name of "Logan sandstone." The whole thickness of the Waverly formation is about 640 feet. Fucoid stems are abundant and in the Logan sandstone in addition to these are found three varieties of an unnamed vegetation.

The Maxville limestone, lying directly above the Logan sandstone, is overlaid by a few feet of soft, coarse sandy shale and 40 to 50 feet of a soft laminated sandrock. Above this is a coarse sandrock rich in impressions of Lepidodendra. A considerable collection of fossils was obtained from the Maxville limestone at Newtonville, Muskingum County. A list of species and genera is given, of which eight species are Chester types and two are identical with species from the St. Louis limestone, leading the author to conclude that this Maxville limestone represents the Chester group of the Lower Carboniferous limestone series, while there may be some representation of the St. Louis limestone at some of the outcrops. These local patches of Maxville limestone never exceed 15 to 20 feet in thickness, and are generally no more than 8 to 10 feet thick, while in Kentucky the limestone is found nearly 100 feet thick.

The true Coal Measures Conglomerate is seen resting upon the Logan or Upper Waverly over limited areas. In general where there is Maxville limestone there is no Conglomerate.

In Vinton County a section is given showing the Waverly Conglomerate and the Logan sandstone extending up to the coal.

No true Coal Measures Conglomerate is found, but the coal, with its superincumbent shales, rests directly upon the Logan sandstone. This valuable section tends to verify deductions made elsewhere in regard to the Waverly conglomerate, and also in regard to the entire absence over certain large areas of the true Coal Measure Conglomerate. At this place no Maxville limestone was found resting upon the top of the Logan group.

Mr. Read reported that in Holmes County the lowest rocks observed belong to the Waverly sandstone, the ravines sometimes cutting down fully 200 feet into it. The Conglomerate appears above the Waverly in Prairie Township, and has a maximum thickness of 18 feet, with fossils which Mr. Meek determined to belong to the Carboniferous formation, pointing to the deposition of a Subcarboniferous limestone which has been cut out or removed by the agencies which brought in a deposit of the Conglomerate. Generally in the county the Conglomerate is wanting, and is represented in places by a thin layer of coarse sandstone without pebbles, sometimes by hard, compact, white siliceous rock a few inches in thickness and filled with *Stigmaria*, and sometimes the Coal Measures rest directly on the Waverly.

In the second volume of the Ohio Reports[1] the Carboniferous system of Ohio is classified.

[1] Report of the Geological Survey of Ohio, vol. 2, pt. 1, Chapter XXXI, by J. S. Newberry, chief geologist, 1874.

The following is a tabular expression of the classification:

	Feet.
Upper Barren Measures (?)	300
Upper Coal Measures	350
Lower Barren Measures	400
Lower Coal Measures	400
Conglomerate	

Maxville limestone (near Newtonville, Muskingum County, 15 to 20 feet thick, and 8 to 10 feet thick in the counties south).

Cuyahoga shale	150–250	Waverly group.
Berea grit	60	
Bedford shale	75	
Cleveland shale	21–60	
Erie shale (Chemung)		

The "Chemung" of New York is considered to have thinned westward and to be represented in the Erie shale. The Catskill, according to the author's view, thins out and does not appear in Ohio. The Vespertine of Pennsylvania changes its character on passing westward, and is the Waverly group in Ohio. The Umbral of Pennsylvania thins, disappears, or is blended with the Vespertine. The Carboniferous Conglomerate is traced as far as central Ohio. The "Maxville limestone" of Andrews furnished fossils which were submitted to Mr. Meek, who identified them as Chester and St. Louis species.

In the year 1878 Mr. L. E. Hicks published two papers concerning the Waverly group. In the first he stated that considerable discussion had arisen in attempting to synchronize sections in southern and central Ohio with a section at Cleveland, upon which Newberry has based his subdivisions.

The Cleveland section, in descending order, is as follows:

	Feet.
Cuyahoga shale	150 to 250
Berea grit	60
Bedford shale	75
Cleveland shale	21 to 60

The Cleveland shale is the only formation which retains its typical characters in central and southern Ohio. It holds a distinct fauna and, in some places, bears a close resemblance to the Huron shale. "*But the two never exist together in immediate contact.*" The persistency of the Cleveland shale has been demonstrated by its discovery in Delaware County, southern Ohio.[1]

In the second paper Mr. Hicks reported that in central Ohio five distinct members of the Waverly group are found, in descending order, as follows:

	Feet.
5. Licking shales	100–150
4. Black Hand conglomerate, or Granville beds	35–90
3. Raccoon shales	300
2. Sunbury black slate	10–15
1. Sunbury Caliciferous sandrock	90–100

[1] *Discovery of the Cleveland shale in Delaware County, Ohio.* Am. Jour. Sci., 3d ser., vol. 16, pp. 70, 71. *The Waverly group in Central Ohio.* Am. Jour. Sci., 3d ser., vol. 16, pp. 216–224.

The upper limit of this series is determined to be the Conglomerate of the Coal Measures by the presence of Subcarboniferous fossils below. The lower limit is very sharply defined by stratigraphical relations.

No. 5 consists mainly of soft, fine-grained shales, well exposed on Licking River. No. 4, best seen at Hanover and Black Hand, consists of coarse sandstones and conglomerates containing fucoids, with compact drab sandstones and shales at the base. No. 3 occurs along Raccoon Creek in Franklin and Delaware Counties, and is composed of blue and gray shales filled with nodular masses of iron ore. No organic remains except fossil sea-weed have been found in this deposit. No. 2 contains fossil remains of fish and corresponds very closely with beds in northern and southern Ohio. No. 1 is made up of compact and shaly sandstones, with alternating shales and limestones, and is well exposed on Rattlesnake and Walnut Creeks.

In regard to the determination of this series of rocks as Devonian or Carboniferous, the author concludes that there is "good reason for retaining the Cuyahoga sub-group in the Carboniferous, whatever may be done with the rest of the Waverly."

Mr. Edward Orton,[1] in 1882, in a paper on the bituminous matter of the black shales, further discussed the classification of the Waverly.

From the author's examination of the various black shales outcropping in Ohio and neighboring States, he concludes that the Huron and the Cleveland shales of Newberry, separated in the eastern part of Ohio by the greenish Erie shales, form a continuous series farther west and constitute a mass from 250 to 350 feet in thickness, which must be regarded as all of Devonian age. For this shale he proposes to retain the name "Ohio, Black shale," applied to it by N. S. Shaler in the Geology of Kentucky. The author recognized a second shale of similar nature in Ohio, situated about a hundred feet above the top of the former, called by Andrews the "Waverly Black shale." It was further defined by Meek, who separated it from the Cuyahoga shale by its fossil contents and called it the "Berea shale." It immediately overlies the Berea sandstone and forms the roof of most of the quarries of this famous sandstone. These three black shales, the Huron and Cleveland of Newberry and the Berea of Meek, are alike in being of marine origin and in being strongly bituminous. Analysis shows them to contain 8 to 20 per cent of organic matter, and frequently they have taken fire from burning brush heaps, and cases are recorded of their continuing to burn for weeks when once thus kindled. The bituminous matter in them was supposed by Newberry[2] to have originated from the decomposition of the "vegetation which lined the shores and covered the surface of a quiet and almost land-surrounded sea," like a Sargasso sea.

[1] Orton, Edward: A source of the bituminous matter in the Devonian and Subcarboniferous black shales of Ohio. Am. Jour. Sci., 3d ser., vol. 24, pp. 171–174.

[2] Geol. of Ohio, vol. 1, p. 156.

Since the writing of that report, the author had discovered several microscopic forms of vegetation occurring in these bituminous shales in great abundance. Dr. Dawson had previously observed these bodies, and recognized them as the spore cases of some lycopodiaceous plant, and named them *Sporangites Huronensis*.[1]

The author supposes that the great accumulations of gas and oil that have been found in the Devonian and Subcarboniferous formations of Pennsylvania, West Virginia, and Ohio are to be traced to the further distillation or decomposition of the bituminous matter, particularly the spore cases originally deposited with these black shales, a theory which was first outlined by Newberry,[2] although the presence of the spore cases was then unknown. To the spore cases the author would attribute the chief supply of bituminous matter.

In 1883 H. S. Williams[3] reported the discovery of a fauna in the midst of the upper Devonian rocks of New York, having a decided carboniferous aspect, but closely related to a fauna heretofore known in America only at the base of the Mississippian series in Iowa.

At the base of the Chemung group at Ithaca and High Point, Naples, New York, the author found a fauna which is strikingly similar to a fauna found at Lime Creek, near Rockford, Iowa. Although the general aspect of the fauna is Carboniferous, yet the occurrence of several of the species in the Chemung rocks requires consideration. The Lime Creek fauna was ascribed to the Hamilton group in 1858 by James Hall, but it was afterwards, in 1873, by him and by R. P. Whitfield referred to the "Chemung group."

By a close comparison of the faunas and minute and accurate examination of the specific relations of these faunas to each other, the author is convinced that the deposits of Lime Creek, Iowa, and all deposits carrying a like fauna, are not Lower Carboniferous, but are "geological equivalents of the Chemung of the East."

Mr. S. Calvin[4] took exception to the conclusions of Williams concerning the "strikingly Carboniferous aspect of the Lime Creek fauna," claiming, after an examination of the fossils, that they exhibit rather a Devonian and Silurian aspect, and Williams[5] replied.

The importance of the discovery consisted in the recognition of traces of the fauna, which is Carboniferous in its aspect, in America before the close of the Devonian in New York. The recognition of the same in Iowa proved the appearance there of a fauna of true upper Devonian age; that is, more recent than the Hamilton and older than the typical Kinderhook faunas of the Mississippian area.

---

[1] On spore cases in coals; by J. W. Dawson, LL. D., F. R. S. Am. Jour. Sci., 3d ser., vol. 1, pp. 256–263

[2] Agricultural Report of Ohio in 1869.

[3] Williams, Henry S.: On a remarkable fauna at the base of the Chemung group in New York. Am. Jour. Sci., 3d ser., vol. 25, pp. 97–104.

[4] Calvin, S.: On the fauna found at Lime Creek, Iowa, and its relation to other geological faunas. Am. Jour. Sci., 3d ser., vol. 25, 1883, pp. 432–436.

[5] Williams, Henry S.: Equivalency of the Lime Creek beds of Iowa. Am. Jour. Sci., 3d ser., vol. 25, 1883, p. 311.

James Hall,[1] in a paper before the American Association, discussed the limitations between the Chemung and Waverly groups, according to paleontological evidence. *Spirifera disjuncta* is considered as characteristic of the upper part of the Chemung. Concerning the sandstones and conglomerates which had been considered as of Carboniferous age, it has been found by a study of the fossils that they represent the upper member of the Chemung group. Above them occurs a series of non-fossiliferous shales of unknown thickness. The correlation of this series of rocks was studied by Mr. C. E. Beecher, who prepared a section exhibiting about 1,500 feet and a list of fossils characteristic respectively of the Chemung group and of the Waverly group following it.

From the record of a well in Cleveland, Ohio, Edward Orton[2] determined the thickness of the shales below the Berea grit.

This well was commenced about 760 feet above tide-water and about 75 feet below the Berea grit. The first rock met was Bedford shale, followed by the Devonian shales, classified by Dr. Newberry as the Cleveland, Erie, and Huron divisions, and having a thickness of 1,300 feet.

In the years 1885 to 1888 C. L. Herrick[3] applied to the solution of the Waverly problem the new methods of correlation previously elaborated by Williams in the interpretation of the upper Devonian formations. (See chapter on the Chemung-Catskill problem.)

This paper is a fine illustration of what can be done in the way of dissecting out the individual faunas, showing their composition, and determining their affinities with faunas of other regions by a minute study of local geology.

Although the study was primarily of a local series of faunas, the author has made abundant use of material from other regions for comparison. The result is that we have a valuable series of the successive faunas of the Lower Carboniferous formations of central Ohio, which will serve as standards in all future work in correlation.

The great mass of the paper is devoted to specific descriptions; the final results of the study are given in volume IV.[4]

The section is divided into three parts or divisions by two conglomerates; these are subdivided into ten zones, and at the close a list of 321 species is given with the particular position or range in this scale of each species.

---

[1] Hall, James: Note on the intimate relations of the Chemung group and Waverly sandstone in northwestern Pennsylvania and southwestern New York. Am. Assoc., Proc., vol. 33, 1884, pp. 416–419.

[2] Orton, Edward: The record of the deep well of the Cleveland Rolling Mill Company, Cleveland, Ohio. Am. Assoc. Proc., vol. 34, 1885, pp. 220–222.

[3] Herrick, C. L.: A sketch of the geological history of Licking County, accompanying an illustrated catalogue of carboniferous fossils from Flint Ridge, Ohio. Denison Univ., Bull., vol. 2, pp. 5-68, 144–148; vol. 3, pp. 13–110; vol. 4, pp. 11–60, 97–123, 1885–1888, with numerous plates illustrating the fossils.

[4] Ibid., pp. 95–114.

The following classification[1] modified from that of Mr. Edward Orton, is given by the author:

			Feet.
Cuyahoga or Waverly series...	Logan	Keokuk	100–150
		Burlington	
	(Conglomerate II.)		
	Kinderhook		50–60
	(Conglomerate I.)		
Berea or Transition Series (Western equivalent of upper Chemung).	Waverly shale		40
	Berea shale		200–400
	Berea grit		50–60
	Bedford shale		50
	Cleveland shale (local)		50
Erie shale.—Eastern or typical Chemung, lower part			100

The classification adopted in his tables is as follows:

III. *Keokuk and Burlington groups*, Upper Waverly (Upper Logan), separated into three zones in the table, but into five on p. 100 of the text, and there amounting to 80 feet of thickness, or not over 125 feet.

II. *Kinderhook* (part or all), middle Waverly.

This is subdivided into two zones in table, but into four zones on p. 101; the uppermost of which is Conglomerate II; the thickness, 52 feet, without the Conglomerate, which is but a few inches or feet in the specific cases given.

I. *Transition zone.*—Devonian, in part equivalent to Chemung and Portage.

The upper zone of this division is the Conglomerate I, 18 inches thick in one of the sections. In the table five zones are mentioned, on pages 100 and 101; seven zones are given, about 350 feet in thickness and not over 500 feet.

Below this is the *Bedford shale*, 51 feet (Hamilton facies in Chemung association), with the *Black or Hamilton shale* next below.

He concluded that his middle Waverly "is representative of the Catskill," but is not strictly equivalent to it.

The "Berea shale" is more than Orton's black shales, so named, but "the greater part of the shales below the Kinderhook."

He did not consider it necessary "to conclude from the fact that the Erie shales are of Chemung, age that all which lies stratigraphically above the Erie is certainly later faunally than the top of the Chemung as seen in New York strata."[2]

Above the Waverly group traces of the higher faunas were seen in the "Maxville limestone," east of Rushville. This "Maxville limestone" fauna is correlated with the Chester limestone of the interior.[3]

The latest systematic classification of the rocks of Ohio is reported in the sixth volume of the Geological Survey of Ohio.[4] This will exhibit the present state of development of correlations for the State:

	Feet.	
18. Glacial drift	0–550	
17. Upper Barren Coal Measures	500	Carboniferous.
16. Upper Productive Coal Measures	250	
15. Lower Barren Coal Measures	500	
14. Lower Productive Coal Measures	250	
13. Conglomerate group	250	

[1] Herrick, C. L.: A sketch of the geological history of Licking County, accompanying an illustrated catalogue of carboniferous fossils from Flint Ridge, Ohio. Denison Univ., Bull., vol. 4, pp. 105–106

[2] Ibid., p. 111.

[3] *Ibid., vol. 3, pp. 21–23.*

[4] *Vol. VI., Economic Geology*, by Edward Orton. Columbus, 1888.

12. Subcarboniferous limestone, Maxville, Newtonville, etc.		25	Subcarboniferous.
11. Waverly group..	11e. Logan group	0–350	
	11d. Cuyahoga shale	150–450	
	11c. Berea shale	20–50	
	11b. Berea grit	3–160	
	11a. Bedford shale	50–150	
10. Ohio shale	10c. Cleveland shale. 10b. Erie shale. 10a. Huron shale.	250–3,000	Devonian.
9. Hamilton shale, Olentangy shale		25	
8. Devonian limestone, Upper Helderberg or Corniferous, including West Jefferson sandstone		75	
7. Lower Helderberg limestone, etc.			

In this classification the Logan group is the equivalent of the Olive shales of Read, the Logan sandstone and the Waverly Conglomerate of Andrews. The "Berea shale" is a name proposed by Mr. Meek for the "Waverly black shale" of the reports. The "Waverly group" is differently delimited from the original Waverly group of the first and second reports, by the addition of the Logan group at the top and the exclusion of the Cleveland shale at the bottom. The reason for including the Cleveland shale in the Devonian was explained by Dr. Orton in previous papers. It is because of structural consideration which led to associating the three shales of Newberry in one formation, though there were recognized fossils in some of them which have been regarded as strictly belonging to the higher fauna.[1]

The correlation of the Goniatite limestone of Rockford, Indiana, involved a number of disputed questions, in all of which the fossils pointed to the right interpretation, while the apparent stratigraphy was misleading.

The elements of the problem were these: At Rockford a limestone, rich in Goniatites, was found above the black shale, and stratigraphically below arenaceous deposits and shales, which in other places were followed by the Mississippian limestone. In 1860,[2] a number of Goniatites and other fossils were described, and the author, Mr. James Hall, reported the limestones as Marcellus black shale. He had previously interpreted the black shale of the Southwest as Marcellus, and as the Marcellus shale of New York in calcareous layers was rich in Goniatites, he inferred that the bed at Rockford was the equivalent.

In this paper he said:

> The parallelism of these localities is inferred from the fact that the stratum containing the Goniatites is clearly above the limestone of the age of the Upper Helderberg group, and below the sandstones which are recognized as of the age of the Chemung group of New York. The exposures at the immediate locality are obscure; but the black shale, which I regard as the continuation of the Marcellus shale, occurs in the immediate neighborhood.[3]

[1] Vol. VI., Economic Geology, by Edward Orton Columbus, 1888, p. 29.
[2] Thirteenth Report to the Regents on the State Cabinet of Natural History, Albany, N. Y.
[3] Ibid., p. 95. (See Cristy's paper on the Goniatite limestone 1851).

In 1861, Messrs. Meek and Worthen replied, and gave their interpretation of the correlation. This paper, like that of M. de Verneuil, was based upon the evidence of fossils, and it augmented the arguments of the learned French palæontologist. The following is an abstract of the paper.

Messrs. Meek and Worthen,[1] after carefully comparing fossils in the Illinois State geological collection with specimens from the Goniatite bed of Rockford, Indiana, came to the conclusion that this bed was also represented in Illinois, Missouri, and Iowa, and that its stratigraphic position is much higher than that given it by Hall. They found that the black slate always occurs beneath the limestone, and that the latter is of the same age with the Chouteau limestone of Swallow, which had been placed on a parallel with the Chemung group, because it contained many fossils found in other beds in the West referred by Hall to the Chemung group.

A section is given showing the position of the Chouteau limestone with regard to the other Western formations, beginning with the Burlington limestone, which is acknowledged to be Carboniferous, and extending down to the Hamilton group, thus:

	Feet.
1. Burlington limestone attaining a thickness of	200
2. Chouteau limestone	100
3. Vermicular sandstone and shale	65 to 100
4. Lithographic limestone (rather local)	60
5. Black slate	30 to 40
6. Hamilton group	120

Numbers 2, 3, 4, are included by Swallow in the "Chemung." The Black slate is shown to come in everywhere above all the well-defined Hamilton group beds, and the authors assert that as the Chouteau limestone comes directly beneath the Burlington limestone and considerably above the horizon of the Hamilton group beds of the West as well as above the Black slate, therefore its representative in Indiana, the Goniatite bed at Rockford, can not be referred to any part of the Marcellus shale at the base of the Hamilton group. Neither can the Black slate be said to represent the Marcellus shale, as that lies at the base of the Hamilton group, and the Black slate is always found above the Hamilton. The position of the Black slate, they maintain, is more nearly that of the Genesee slate as suggested by M. de Verneuil.

The fossils of the Rockford limestone, including the Goniatites, were considered by the authors as more nearly allied to the Carboniferous forms than to those of the New York rocks; examples are given to prove this statement, and a section to illustrate the close relations between the Chouteau limestone (equivalent to the Rockford limestone) and the Burlington beds in Illinois. Reference is made to a paper of

[1] Meek, F. B., and A. H. Worthen. Remarks on the age of the Goniatite limestone at Rockford, Indiana, and its relations to the "Black slate" of the Western States and to some of the succeeding *rocks above* the latter. Am. Jour. Sci., vol. 32, 1861, pp. 167-177, 288.

Mr. C. A. White, in which he "shows that, out of a list of 102 described species occurring in the Burlington limestone, 15 commenced their existence in the beds below, referred by Hall to the Chemung, which, as is well known, represents the Chouteau limestone of Swallow."

After noting the intimate connection between these beds and the Carboniferous rocks above and remembering that the Chemung group in New York and Pennsylvania is covered by another Devonian formation (the Old Red sandstone) between 2,000 and 3,000 feet thick, the questions arose, should these Chouteau beds be referred to the Chemung Horizon? Is it possible that a great formation like the Old Red sandstone, with its own fauna, is wanting here between the Chouteau and Burlington limestones? The authors say, if asked what is to be done with the fossils of these rocks apparently identical with the Chemung forms, that they do not consider this identity proved, and find, if some are undistinguishable from Chemung species, there are numerous other fossils totally distinct from them, closely allied with Carboniferous forms, and even identical with them. Mr. C. A. White had inferred from the presence of these "Chemung" species "that they originated at the east and were migrating westward during the time that the bottom of the Chemung seas was sinking and receiving upon it the deposit of the Old Red sandstone, thus making these Devonian rocks equivalent to the Chemung of New York, and contemporaneous, at least in part, with the Old Red of the Catskill Mountains." But the authors add that in that case they should not refer the rock in which the Chemung forms occur to the Chemung, but either to the Old Red or to the Carboniferous, as in using these names they refer to a period of time, as well as to a group of strata, and they consider that the entire group of fossils is far more nearly allied to the Carboniferous than to the Old Red.

In conclusion they affirm "that the relations between the Chouteau and Burlington limestones in Missouri, Iowa, and Illinois, where both occur together, as well as of the affinities of the fossils found in the former in the States mentioned, and at Rockford, Indiana, show that it should probably be referred to the Carboniferous system, or, at any rate that it is much more recent than the Chemung, and not equivalent to any New York rock."

In a note on p. 288 of vol. 32, the authors propose the name "Kinderhook Group" for "the beds lying between the Black slate and the Burlington limestone which have heretofore been considered the equivalents of the Chemung group of New York."

Messrs. C. A. White and R. P. Whitfield dissented from the views expressed in the above paper in an article published in the Proceedings of the Boston Society,[1] the same year. Their chief objection was to

[1] "Observations on the rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species from the same horizon at Burlington, Iowa." by C. A. White and R. P. Whitfield. Boston, Soc. Nat. Hist., Proc., vol. 8, pp. 289-306. Reviewed by "Anon." Am. Jour. Sci., 2d ser., vol. 33, pp. 422-426.

the correlation of the beds lying between the horizon of the "Black shale" and the base of the Burlington limestone as carboniferous. Their argument was as follows: On passing westward from New York, the representative of the Chemung in Ohio offers considerable change in the paleontologic characters, and between the correlated faunas of Ohio and Michigan a still greater difference is seen. Yet we feel warranted in regarding them "as of the age of the Chemung group of New York, and, so far as we know, no one has questioned it.[1]" They were "confident that some of the species found at Burlington and other places in the west of the same geological horizon are identical with some of those found in the Chemung rocks of Ohio, which rocks can be traced continuously to New York," and, "notwithstanding their carboniferous character, we think their reference to the Chemung of New York legitimate and proper.[2]" They accounted for M. de Verneuil's correlation of the "Chemung" of Ohio as carboniferous by supposing that he was ignorant of the tendency to change on passing westward, which they believed belonged to the faunas. They further maintained that "a direct continuity of the strata of the Chemung Rocks of New York can be traced from that State to those of Ohio," and that Hall considered that but for the Cincinnati axis the continuity could be traced to the Mississippi Valley. They noticed the difference in faunas, but believed with Hall that a stratigraphic continuity had been established.

When we examine the argument critically, we find that the error was at the start, on passing from Chautauqua County, New York, to Ohio. It was supposed that continuity of strata had been traced, and, in spite of the difference observed between the species in the Ohio rocks and those of the New York Chemung, the belief in the identity of strata led to a theory to account for the difference of fossils.

This is one of the best illustrations we have seen of the principle that correlations by lithologic characters cannot be relied on, even when the continuity is affirmed by a careful geologist after a special survey. Whereas the testimony of fossils can always be relied on to the extent and with the precision which our ability to interpret them will permit, and the reason is not far to seek. Petrographic characters have no relation to age. The characters of fossils are intimately associated with the time and environment of the living organisms they represent.

[1] "Observations on the rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species from the same horizon at Burlington, Iowa," by C. A. White and R. P. Whitfield. Boston. Soc. Nat. Hist., Proc., vol. 8, pp. 289–306. Reviewed by "Anon." Am. Jour. Sci., 2d ser., vol. 33, p. 200.

CHAPTER IX.

THE PERMIAN PROBLEM OF KANSAS AND NEBRASKA, 1858-1886.

The determination of the upper limit of the Paleozoic rocks of America was a problem which did not trouble the students of the geological formations east of the Mississippi River until it had been suggested by studies farther west. The Carboniferous period in the Appalachian province was terminated by an uplift, which may have taken place during the Permian epoch, as suggested by Messrs. Fontaine and White, but stratigraphically the system was terminated by cessation of deposition, the result of the permanent elevation of the great mass of the Paleozoic deposits above ocean level. West of the Mississippi, at the western boundary of the outcrop of the Carboniferous system, in Nebraska, Kansas, and Texas, and around elevated masses in Dakota and New Mexico, the Permian problem arose for solution.

The first announcement of the discovery of Permian fossils was made in 1857, in a letter to F. Hawn, dated September 3, 1857, written by F. B. Meek, regarding the identification of some fossils sent by the former to the latter for that purpose. Mr. Meek's identification of the forms was recorded in written memoranda in the Smithsonian Institution January 19, 1858. Mr. Hawn had sent similar fossils to Mr. Swallow, who reported their identification with Permian forms to the St. Louis Academy of Science in a letter dated February 18, 1858, which was read February 22. Mr. Meek communicated a paper announcing the discovery of fossils "indicating Permian rocks in Kansas" to the Albany Institute, March 2, 1858, and also in a letter to the Philadelphia Academy of Natural Science, of the same date.[1] Following these announcements came fuller descriptions and other discoveries in other parts of the outcrop of the same terrane, made by J. G. Norwood, B. F. Shumard, and others.

At the beginning of 1858, F. Hawn was United States geologist in Kansas; G. C. Swallow was State geologist of Missouri; F. B. Meek was assisting as paleontologist in the explorations of F. V. Hayden, United States geologist in the Territories; J. G. Norwood was State geologist of Illinois, and B. F. Shumard was assisting G. C. Swallow in Missouri.

The Coal Measures had been studied and pretty thoroughly classified for all the States east of the Mississippi. Their marine fossils had been gathered in most of the States, and partially identified.

[1] Am. Jour. sci., 2d ser., vol. 44, pp. 38, 39.

The Permian system had been named and defined by Murchison in the report on the geology of Russia.[1]

William King's monograph of the Permian fossils of England was published in 1850.

Murchison's idea of the "Permian" was, that it was a system equivalent in rank to the Silurian or Carboniferous, and that it was characterized "by one type of animal and vegetable life." The question as to whether this idea was a correct one did not come definitely before the American geologists till a later period. When they discovered above the Coal Measures fossils indicating a Permian fauna, the question was as to whether or not the Permian system was present in the American geological series.

Those who took the most active part in the discussion were Messrs. Meek, Hayden, Swallow, Shumard, Hawn, Marcou, Geinitz, Norwood, Newberry, and C. A. White.

The typical sections whence the fossils came were along the Kansas River in northeast Kansas, and in Nebraska and south and west of these (at that time) Territories. In Swallow and Hawn's paper on "The Rocks of Kansas"[2] is given the typical Kansas section made by F. Hawn, consisting of—[3]

	Feet.	Strata Nos.
System I. Quaternary	169	1–3
System II. Cretaceous	72	4–5
System III Triassic(?)	420½(?)	6–25
System III. Permian:		
Upper Permian	263	26–31
Lower Permian	557	32–70
System IV. Carboniferous:		
"Coal Measures, probably above the upper Coal Measures of Missouri"	1,073	

The section made independently by Messrs. Meek and Hayden, including about the same section of rocks, is published in their paper on "Geological Explorations in Kansas Territory."[4]

The section is entitled "General section of the rocks of Kansas Valley from the Cretaceous down, so as to include portions of the Upper Coal Measures." Forty strata are given, numbered from above downward, 1 to 40. The point where they draw the line between the Upper Coal Measures and what may be called the Permian is at the top of their stratum No. 11. No. 10 above contains well authenticated Permian fossils; the locality of both sections is on Cottonwood Creek, in the neighborhood of Fort Riley. Most of the fossils reported as Permian by Swallow and collected by Hawn were from the Valley of the Cottonwood and from Smoky Hill Fork.

[1] Murchison, Verneuil, and Keyserling in 1845. The first announcement of the system was made in a letter from Murchison dated Moscow, September, 1841, and published in the Philosophical Magazine, vol. 19, p. 419.

[2] Trans. St. Louis Acad. Sci., vol. 1, pp. 173–197.

[3] *Ibid., pp.* 174–175.

[4] *Proc. Acad. Nat.* Sci., Phil., vol. 2, pp. 8–30.

In the early discussions Meek and Hayden recognized only "the Upper Permian" of Swallow as equivalent to the Permian of Europe; the "Lower Permian" of Swallow they considered as intermediate, and called it "Permo-Carboniferous." After a thorough study of the fossils in 1865 and later, Mr. Meek dropped the term "Permo-Carboniferous," and included all the rocks, except the upper zone of Swallow and the barren rocks above and their equivalents, in the Upper Coal Measures.

The facts emphasized by Mr. Meek were the gradual coming in of the Permian faunas at the top of the Coal Measures, followed above by a series of barren ferruginous beds and magnesian limestones with gypsum, and these followed by the Cretaceous. But all along this southwestern border of the Carboniferous there was a gradual passage from the Coal Measures lithology to that of the Permian type above, with no stratigraphic break, and a gradual change in the faunas, the Permian types coming in during the prevalence of Upper Coal Measure types, and by degrees increasing in dominance till the latter had nearly ceased.

There was nothing to suggest a distinct system except the European classification, and in ignorance of European Geology no one would have thought to draw a line of higher value than separating two étages, between the two sets of rocks.

The correlation with the European Permian was made on purely paleontological grounds.

A letter from G. C. Swallow to B. F. Shumard was read before the St. Louis Academy of Science,[1] announcing the identification of fossils collected by Hawn from Kansas. The letter states:

> All of the described fossils, with perhaps two exceptions, are identical with Permian species of Russia and England, while all of the new species appear to be more nearly allied to Permian forms than to any other.

At the same meeting a paper was read by Messrs. Swallow and Hawn.[2] Mr. Swallow considered the evidence of identity of fossils as sufficient to justify the decision that "the rocks are Permian."[3]

Messrs. Meek and Hayden[4] announced to the Philadelphia Academy of Science, March 2, 1858, by letter, the identification of fossils sent Mr. Meek by Mr. F. Hawn from near the junction of Solomon's and Smoky Hill Forks of Kansas River, "indicating the probable existence of Permian rocks in Kansas Territory."

The fossils were in the form of casts in a yellowish magnesian limestone, were "unlike any forms known to them from the Carboniferous

---

[1] Swallow, G. C.: Discovery of Permian Rocks in Kansas. Read February 22, 1858. St. Louis Acad. Sci., Trans., vol. 1, 1860, p. 111.

Shumard, B. F.: Discovery of the Permian formations in Mexico. Read March 8, 1858. St. Louis Acad. Sci., Trans., vol. 1, 1860, p. 113.

Swallow, G. C., and F. Hawn: The Rocks of Kansas. St. Louis Acad. Sci., Trans., vol. 1, 1860, pp. 173-175. This paper was communicated to the Society February 22, 1858.

[2] "The Rocks of Kansas, with descriptions of New Fossils from the Permian formation in Kansas Territory." This was published in full later, in the same vol. 1, pp. 173-197.

[3] The same announcement appeared in the American Journal of Science, March, 1858. (Vol. 25, p. 305.)

[4] Proc. Phila. Acad. Sci., vol. 10, pp. 9, 10.

system," and were "very nearly allied to types considered characteristic of the Permian of the Old World." The letter states that when Major Hawn was informed of the identification, several months previous, he reported that the bed from which the fossils were obtained was above the well marked Coal Measures, "and seems to have been deposited upon an uneven surface."

On the same day that this announcement was made to the Philadelphia Academy, a paper entitled "Description of new organic remains from northeastern Kansas, indicating the existence of Permian rocks in that Territory," by Messrs. Meek and Hayden, was read before the Albany Institute.[1]

In this paper, which was read before the Albany Institute March 2, 1858, the authors announce that fossils had been examined by them, received from Maj. F. Hawn "from near the mouth of the Smoky Hill Fork of the Kansas River, in a hard, rather compact, yellowish, brittle magnesian limestone." They differed "from forms known to us in any part of the Carboniferous system, yet were more nearly like Upper Carboniferous than Triassic or Jurassic types. * * * Suspecting this rock might represent the Permian system of the Old World, a hasty comparison was made * * * which almost established the conviction (six or eight months ago) that they belonged to that epoch."

"From the unquestionable relations of some [of the species] and the apparent affinities of others, taken in connection with the lithological characters and the stratigraphical position of the rock in which they occur, we think there is scarcely room to doubt that it is of Permian age."[2]

These announcements of the Permian character of the fossils discovered by F. Hawn in Kansas were followed later by the recognition of Permian fossils by B. F. Shumard from the white limestones of the Guadalupe Mountains, New Mexico, March 8, 1858, collected by G. G. Shumard.[3]

J. G. Norwood, April 5, 1858, announced to the St. Louis Academy that comparison of fossils found in the upper part of the sections in Bureau, La Salle, and Henry Counties, Illinois, with those identified by Messrs. Swallow and Meek, had convinced him that the upper beds of his sections were of the same age as those belonging to the Permian rocks of Kansas.[4]

---

[1] Trans. Alb. Inst., vol. 4, pp. 73–88. Also, Am. Jour. Sci., vol. 25, pp. 440, 441.

[2] The following species are described: *Monotis Hawni* (p. 76), *Myalina* (*Mytilus*) *perattenuata* (p. 77), *Bakevellia parva* (p. 78), *Leda* (*Nucula*) *subscitula* (p. 79), *Edmondia? Calhouni* (p. 80), *Pleurophorus? occidentalis* (p. 80), *P.* (*Caritina*) *subcuneata* (p. 81), *Lyonsia* (*Penopea*) *concava* (p. 82), *Penpea Cooperi* (p. 83), *Nautilus eccentricus* (p. 83).

[3] See Trans. St. Louis Acad. Sci., vol. 1, p. 113; also March 23, 1858, Proc. Acad. Nat. Sci., vol. 10, p. 14. The description of these fossils is published in the transactions of the St. Louis Academy of Sciences, vol. 1, pp. 387–403.

[4] Trans. St. Louis Acad. Sci., vol. 1, p. 115. See also Norwood, J. G.: The Permian in Illinois, Am. Jour. Sci., vol. 26, 1858, pp. 129, 130.

Hayden, F. V., and F. B. Meek. [On the probable existence of Permian rocks in Kansas.] (Read *March 2, 1858.*) Philadelphia Acad. Sci., Proc., vol. 10, 1859, pp. 9, 10.

Messrs. Swallow and Hawn,[1] in "The Rocks of Kansas," 1858, gave a section with 820 feet of "Permian rocks" above the Coal Measures, and still higher, 420½ feet of Triassic(?). They enumerate 72 species as Permian; 30 of these are identified with species before described; others are doubtfully referred to described species or are given new names.

In the article in the American Journal of Science, Swallow[2] acknowledged that Mr. Meek first discovered the Permian character of the Kansas fossils, and communicated it to Hawn September 3, 1857, and verbally to a friend at the Smithsonian January 17, 1858, and to Leidy the 16th of March, 1858, and he stated that Hawn first received the idea from Meek.[3]

Messrs. Hayden and Meek[4] found upon more thorough study of section and fossils, and comparison with the Nebraska section, that only Swallow's Upper Permian of Kansas is equivalent to the European Permian, and Swallow's Lower Permian, with several hundred feet of what he regarded as the top of the Coal Measures, in which *Monotis* was discovered by Meek, they call transitional and name "Permo-Carboniferous," or, if it must be placed one side or the other of the line, suggest that it be put in the Carboniferous.[5]

In a paper[6] read in May, 1857, Meek and Hayden presented a section of the rocks of Nebraska in which the base, of unknown thickness, is called "Carboniferous." It is seen along the Missouri River at De Soto; and at Council Bluffs, at low stages of the river, fifteen or twenty feet of it are exposed. This part is a yellow limestone, with *Fusulina cylindrica* and other Coal Measure fossils.

Above this the section for five members is called "Cretaceous."

No. 1 is described as yellowish and friable sandstones with alternation of dark and whitish clays, seams and beds of impure lignite, fossil wood, impressions of dicotyledonous leaves, *Solen*, *Pectunculus*, *Cyprina*, etc. This bed is "not positively known to belong to the Cretaceous system." The authors correlate this No. 1 with *f* of the New Jersey sections furnished by G. H. Cook, "mainly resting the opinion upon stratigraphic and lithologic evidence." Its correlation in the Alabama section is with E of Alexander Winchell's section. (See Table, beyond.)

In the same paper is given a section of the rocks of Kansas furnished by Hawn. It is a compiled section, based upon his observations made

[1] Reviewed Am. Jour. Sci., vol. 26, p. 115, and substantially the same paper read before the Am. Assoc. Adv. Sci., at Baltimore, lacking the descriptions, and printed in the Am. Jour. Sci., vol. 26, p. 182.

[2] Vol. 25, p. 188.

[3] See also Hayden's paper, Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 32-40.

[4] Am. Jour. Sci., vol. 27, 1859, pp. 31-35.

[5] See also notes explanatory of a map and section illustrating the geological structure of the country bordering on the Missouri River, from the mouth of the Platte River to Fort Benton, in latitude 47° 30′ N., longitude 110° 30′ W., by F. V. Hayden, M. D., Proc. Acad. Nat. Sci., Phila., vol. 9, 1857, 109–116.

[6] Descriptions of new species and genera of fossils collected by Dr. F. V. Hayden in Nebraska Territory, under the direction of Lieut. G. K. Warren, U. S. Topographical Engineer; with some remarks on the Tertiary and Cretaceous formations of the Northwest, and the parallelism of the latter with those of other portions of the United States and Territories, by F. B. Meek and F. V. Hayden, M. D., Proc. Acad. Nat. Sci., Phila., vol. 9, 1857, pp. 117–148.

in the country east of the sixth principal meridian and between the northern boundary of Kansas and the Republican Fork of the Kansas River. In this section the lowest bed, *m*, a siliceous limestone, is regarded as Carboniferous. The strata *c* to *l*, next above, are considered as equivalent to No. 1 of the Nebraska section. The lower part of these beds, *f* to *l*, is correlated with the Triassic of Marcou; the higher part *a* to *e*, with Marcou's Jurassic. The Pyramid section of New Mexico, according to Mr. Marcou, is given, p. 132. The lower members of this section, *c*, *d*, and *e*, called Jurassic by Marcou, and *f*, called Triassic by him, are correlated with No. 1 of the Nebraska section.[1]

In a second paper by F. V. Hayden,[2] a strip of Permian is colored in Kansas between the Carboniferous and the Cretaceous, a little west of Nebraska City and west of Fort Riley, in what in the first map was colored Cretaceous. This change is based upon facts reported by Hawn.[3]

It appears from this paper that the insertion of No. 1 of the Nebraska section of the Cretaceous was made upon the report of Hawn as to the species contained in it or below it, which belonged to genera characteristic of the Cretaceous.[4] Upon examination of fossils derived from No. 1 they were found by Meek to be of Permian or Carboniferous types. The presence of the leaves of dicotyledonous trees was the evidence upon which the authors (Meek and Hayden) relied as positive indication of the Cretaceous system. These occurred above No. 1. The evidence for this correction apparently did not reach the authors in time to adjust the body of the paper.

Meek and Hayden. Nebraska section.	Hawn. N. E. Kansas.	Marcou. Pyramid Mountain, New Mexico.	Winchell. Alabama.	Cook. New Jersey.
Tertiary Miocene.				
Cretaceous No. 5..	.....	.....	A	*a*
No. 4..	.....	.....	B. C. D.	*c. d. e.*
No. 3..	*a*	*a*		
No. 2..	? *b*	*b*		
Permian or Carboniferous No. 1.	*c–l*	*c* *d* *e* Jur.		
		f Trias.	E	*f*
Carboniferous	*m*			

In the Judith River section a bed called "No. 1 (?) is defined, and its true position was uncertain to F. V. Hayden in May, 1857.[5]

B. F. Shumard, in a paper[6] read before the Academy of Science, in

[1] Description of new species and genera of fossils collected by Dr. F. V. Hayden in Nebraska Territory, under the direction of Lieut. G. K. Warren, U. S. Topographical Engineer; with some remarks on the Tertiary and Cretaceous formations of the Northwest, and the parallelism of the latter with those of other portions of the United States and Territories, by F. B. Meek and F. V. Hayden, M. D., Proc. Acad. Nat. Sci., Phila., vol. 9, p. 129.

[2] *Proc.* Acad. Nat. Sci. Phil., vol. 10, pp. 139-158. [3] See note, Ibid., p. 144.

[4] *See note, Ibid., p. 145, 146,* foot-note. [5] Ibid., vol. 9, p. 116.

[6] "*Observations upon* the Cretaceous strata of Texas," by B. F. Shumard, State Geologist, Trans., *vol. 1, No. 4, p. 582.*

St. Louis, in 1860, correlates the lower Cretaceous beds ("Arenaceous and Red River groups") with No. 1, of the Nebraska section; in it are recorded characteristic Cretaceous fossils.

Messrs. Meek and Hayden[1] having examined the fossils and other geological specimens collected by Lieut. G. K. Warren, topographical engineer in and near the Black Hills, Nebraska, gave the succession of geological formations indicated by them.

The main body of the Hills is granite, and superimposed upon it is—

(1) A group of highly metamorphosed sedimentary formations.

(2) A sandstone equivalent to the Potsdam sandstone of the New York series.

(3) Limestones containing fossils which are a mingling of Coal Measure and Lower Carboniferous types.

(4) Two red beds containing specimens of fossils closely allied to Coal Measure forms. These red beds may be of Permian age, though the fossils point rather to the Upper Carboniferous series. It is not improbable that the upper bed may be Triassic or even Jurassic.

(5) Strata containing fossils of Jurassic type. The strata are argillaceous shales and various colored sandstones.

(6) Beds regarded as belonging to the older Cretaceous, though a large portion of them may be Jurassic.

Above all these formations are in regular succession, No. 2, No. 3, No. 4, No. 5, of the Cretaceous series of Nebraska.[2]

Mr. Swallow examined a collection of fossils from the Upper Coal Measures of Kansas Territory, made by Mr. Hawn, compared them with Permian fossils from Russia of Verneuil, and decided that the Kansas fossils are also Permian.

On his journey to New Mexico, J. S. Newberry[3] found Permian fossils in Kansas, and the beds described by Meek and Hayden as between the Lower Cretaceous and the Permian, which they state may be either Jurassic or Triassic. He also saw the same red or brown sandstone from which these gentlemen collected the fossil leaves which Heer and Marcou pronounced to be Miocene, but which Newberry says are the same which mark the base of the Cretaceous in New Jersey, Nebraska, and Kansas. And farther southwest he found this same sandstone overlaid by the same Cretaceous seen by Meek and Hayden surmounting it in Nebraska, these Cretaceous beds containing well known and admitted Cretaceous fossils, and also the very *Gryphæa* relied upon by Marcou to prove the existence of the Jurassic, proving, if Marcou and Heer are right, that the Miocene is older than the Cretaceous and Jurassic.

In New Mexico Mr. Newberry discovered facts sustaining the presence of the Trias there, as in the red gypsum-bearing marls containing cycadaceous plants, similar to those of the Keuper (Upper Trias) of Europe.

In the letter[4] from B. F. Shumard, read by Joseph Leidy, to the

[1] Meek, F. B., and F. V. Hayden: Fossils of Nebraska. Am. Jour. Sci., vol. 25, 1858, pp. 439-441.

[2] Swallow, G. C.: On Permian strata in Kansas. Am. Jour. Sci., 2d series, vol. 25, 1858, p. 305.

[3] Newberry, J. S.: Explorations in New Mexico. Am. Jour. Sci., vol. 28, 1859, pp. 298-299.

[4] *On Permian rocks of New Mexico.* By B. F. Shumard, Phil. Acad. Sci., Proc., vol. 10, 1859, p. 14.

Academy of Science, Philadelphia, the undoubted occurrence of Permian fossils in the white limestone of the Guadalupe Mountains, New Mexico, was announced. The collection consists of forty species, part of which are identical with the Permian forms of England and Russia. Below this limestone is a sandstone containing the same fossils found in the same formation in Missouri, Iowa, and Illinois, "but in New Mexico scarcely a single species ranges from the Coal Measures into the Permian."

Sir Roderick Murchison,[1] in a letter to the editors of the American Journal, expresses his surprise at the statement made by Mr. Marcou with regard to the term Permian, as given by Murchison, for the strata of the government of Perm, which term he considered a very improper one, and also that Murchison has included in his Permian a part, if not the whole, of the Trias.

Considering this a serious charge, Murchison asked an explanation of Marcou of the grounds upon which it was made, and this was finally given in the memoir noticed in this letter. Murchison objected strongly to criticisms upon his work by one who had never been in Russia, spoke of the absolute distinction between the fossils of the Permian group and those of the Trias, whether we refer to the reptiles, fishes, and shells, or to the plants, but Mr. Marcou unites these two deposits in one natural group under the name of New Red sandstone.

The author concludes by requesting the editors to translate into English the last page of Mr. Marcou's memoir, considering it the best argument against the adoption of that gentleman's views that could be produced.

The editors gave the summary referred to, in which Mr. Marcou regards the New Red sandstone, comprising the Dyas and Trias, as a great geologic period equivalent to the Paleozoic epoch, the Carboniferous, Mesozoic, etc., and says that he restricts the limits ordinarily given to the Paleozoic and Mesozoic, and gives them proportions more in harmony with those of the Tertiary and recent epoch, in order to have a well balanced and natural classification. He considers the Carboniferous forms of life found in the lower beds of the "New Red" as a kind of rear guard to the preceding organisms, and the forms found in the upper beds as precursors or advance guard of the Mesozoic populations.

In 1859, Messrs. Meek and Hayden acknowledge their mistake[2] in having placed certain rocks of Kansas on a parallel with No. 1 of Nebraska section, having ascertained by their fossils, which are similar to the Permian of the Old World, that these rocks should be placed lower, and the same was done with the lower 200 feet of Mr. Marcou's

[1] Murchison, Sir Roderick J.: Notice of a memoir by M. Jules Marcou, entitled "Dyas and Trias, or the New Red Sandstone in Europe, North America and India." Am. Jour. Sci., vol. 28, 1859, pp. 256–259.

[2] *Meek, F. B., and F. V. Hayden*: On the so-called Triassic rocks of Kansas and Nebraska. *Am. Jour. Sci., vol. 27, 1859, pp. 31–35.*

Pyramid Mountain section (New Mexico), referred by him to the Trias. These 200 feet the authors consider equivalent to the Kansas deposits between the base of No. 1 and the beds containing Permian fossils, and the rest of the Pyramid section, which he referred to the Jurassic, as equivalent to the Cretaceous formations, Nos. 1, 2, 3, of Nebraska.

The authors refer to their having considered No. 1 as a Cretaceous formation from the presence in it of dichotyledonous leaves (*Ettingshausiana*, etc.), while Major Hawn pronounces this formation in Nebraska, Kansas, and New Mexico, to be Trias, and they give Newberry's opinion after having seen the whole collection, affirming the correlation with the Cretaceous formations. They also speak of the beds between the base of No. 1 and those from which Permian fossils are obtained in Kansas, as possibly Jurassic or Triassic, or both, but do not attempt to define their age with certainty. With regard to the Permian rocks of Kansas, as classified by Swallow and Hawn, they are inclined to the opinion that the lower Permian of these gentlemen should be considered as intermediate in age between the Permian and Upper Coal Measures of the Old World, while the Upper Permian only, of their section, really represents the Permian rocks of Europe, and they propose the name of "Permo-Carboniferous" for this intermediate series, but if this be not adopted, think it should be placed with the Carboniferous rather than with the Permian.

In conclusion, they state that there is no unconformability among all the rocks of Nebraska and northeastern Kansas, from the Coal Measures to the top of the most recent Cretaceous.

Mr. J. C. Norwood,[1] writing to B. F. Shumard, President of the St. Louis Academy of Science, March 31, 1858, spoke of having found in 1855–'56 organisms new to him in the upper beds of the La Salle coal field, which he supposed to belong to the true Carboniferous era. But after the announcement of the existence of Permian rocks in Kansas by Professor Swallow and Messrs. Meek and Hayden, he reviewed some of these fossils found in Bureau, La Salle, and Henry Counties, and became satisfied that the upper beds, at least, of the La Salle rocks are of the same age as those considered Permian in Kansas. The beds are composed of sandstones, conglomerates, magnesian limestones, slates, and red and blue gypseous marls, all of them resting *unconformably* on the underlying beds. Thin seams of coal also occur, showing that if this formation belongs to the Permian period, the great probability is that the upper beds of coal in several sections of the State are of the same age. A section of the rocks at La Salle accompanies the letter.

In 1864 M. Jules Marcou[2] wrote upon the section at Nebraska City and

[1] Norwood, J. C.: Discovery of Permian rocks at La Salle, Illinois. St. Louis Acad. Sci., Trans., vol. 1, 1860, p. 115.

[2] Marcou, Jules: Une reconnaissance géologique au Nebraska. Soc. géol. France, Bull., 2e sér., vol. 21, 1864, pp. 132-146.

vicinity. He regarded the section $\frac{D}{C}\frac{}{B}\frac{}{A}$ as representing in America "la partie supérieure du Dyas d'Europe."[1] Of the section of the bluff at Plattesmouth he said: "elles appartiennent à la partie inférieure du Dyas."[2]

In Missouri he reported islands of Carboniferous in the midst of the Dyas. Two members of the Dyas were recognized, viz, the Rothliegende and the Zechstein.

In regard to Brachiopods as a means of correlation, he remarked:

> Les plus mauvais fossiles dont on puisse se servir comme fossiles caractéristiques des formations, et qu'en réalité ils ne sont même pas du tout des Leitmuschel * * * plus bas même dans la série que les coraux.[3]

Had he appreciated better the value of Brachiopods in making correlations his conclusions might have been more accordant with those of other geologists.

This paper of Mr. Marcou was criticised in 1865 by Mr. Meek,[4] who took issue with him upon almost every point made. Although the discussion was of interest at the time, its rehearsal here may be omitted without loss.

In 1866 Mr. H. B. Geinitz published his description of the fossils collected by Mr. Marcou from the localities in Kansas and Nebraska named in the paper above referred to.[5]

There are mentioned in the work 99 species, 2 of them plants. Of these, 67 were found at the typical Nebraska City section, the zones of which were called, from below upward, A, B, C, D, by Marcou. Sixty-three of the 67 species were from the zone C. Twenty-three species of invertebrates and one plant from the Nebraska City section were identified with already described "Dyas" species of Europe. The author says: "Die bei Nebraska-City vorkommenden Versteinerungen gehören einer Zone an, welche den untersten bis mittleren Schichten den deutschen Zechsteinformation (Oberen Dyas) entspricht."[6]

The Plattesmouth and Rock Bluff sections were thought to represent a lower horizon, the "Fusulinenkalk" or "oberen Kohlenkalk."

The bulk of the work, pages 1 to 72, is devoted to the description of the fossils and their comparison with typical species of the Carboniferous and Permian formations. Although the correlations of the author were based upon this paleontological study, it is impracticable here to discuss the merits of the identifications of species.

In the following year (1867) Mr. Meek made an extended review of

[1] Marcou, Jules: Une reconnaissance geologique au Nebraska. Soc. geol. France, Bull., 2e sér., vol. 21, 1864, p. 137.

[2] Ibid., p. 138 [3] Ibid., p. 146.

[4] Meek, F. B.: Remarks on the Carboniferous and Cretaceous rocks of eastern Kansas and Nebraska, and their relations to those of the adjacent States and other localities further eastward; in connection with a review of a paper recently published on this subject by M. Jules Marcou, in the Bulletin of the Geological Society of France. Am. Jour. Sci., vol. 39, 1865, pp. 157-174.

[5] *Carbonformation* und Dyas in Nebraska, von Dr. H. B. Geinitz, 1866, pp. i-xii and 1-91, Plates I-V.

[6] *Op. Cit.*, p. 89.

Mr. Geinitz's paper.[1] As a preparation for his criticisms Mr. Meek had thoroughly studied the species obtained from the same localities, and before completing the article had gone over the sections from which they were obtained and examined the stratigraphy of the whole region where the rocks in question were exposed, from Iowa across Nebraska, Missouri, and Kansas, collecting fresh materials. He also had access to the numerous collections of the Smithsonian, among which were a considerable number of European Permian fossils. He had the advantage of Mr. Geinitz in his thorough knowledge of the Carboniferous marine fossils of the Mississippi Valley, comprising the fauna with which the fauna above had to be immediately compared. With such preparation he made a careful and critical review of the identification of species and genera made in Geinitz's work. The author differs respecting the identification both of genera and species from Geinitz, and suggests as explanatory of the unsatisfactory identifications made by Mr. Geinitz that the latter was ignorant of the Coal Measure fossils of America, and was therefore not in a position to see the close relationship between the faunas below and those which follow. Mr. Meek had previously noticed in the rocks called Permian by Swallow a mingling of Coal Measure and Permian types, and calls attention to the frequent alternation of beds containing these two types of fossils through considerable thickness of strata which must be regarded as typical Upper Coal Measures. He also remarks that Mr. Geinitz had only descriptions of species already described in America, and had not access to the originals. In his remarks regarding two schools of observers among paleontologists and zoologists he defines the two classes as, "first, those who give wide latitude to genera and species, and second, those who restrict both genera and species within more precise limits." In commenting on *Astarte Nebrascensis* (p. 179) he remarks: "At any rate, specific identification and even generic references of such shells can be admitted only provisionally until the hinge and interior is known." On page 183, commenting on *Rhynchonella angulata* Linnæus of Geinitz, he writes:

> I hope I shall be excused for adding here that the practice of positively identifying species from widely distant parts of the earth upon such merely superficial points of general resemblance, and thus complicating and vitiating all conclusions respecting the geographical and geological range of species, can not be too carefully avoided.

The conclusion reached in this paper regarding the Permian problem is to the effect that the rocks in Nebraska from which the so-called Permian fossils have been obtained contain also a much larger number of characteristic Coal Measure fossils, and therefore that the rocks above the mouth of the Platte River called by Marcou "Mountain limestone," those of Plattsmouth and Rock Bluff called "Lower Dyas"

[1] Remarks on Professor Geinitz's views respecting the Upper Paleozoic rocks and fossils of southeastern Nebraska. By F. B. Meek, Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 170–187, 282–283, 327–338.

by Marcou, and by Geinitz placed in part in the upper "Mountain limestone," and in part in the Upper Coal Measures and the "Upper Dyas" rocks of Marcou and Geinitz at Wyoming, Bennett's Mill, and Nebraska City, with possibly the exception of C and D of the latter place, belong to the horizon of the Upper Coal Measures. C and D he thinks may be equivalent to the "Permo-Carboniferous" of the Kansas section.

All through this region the fossils of the Upper Coal Measures are found either associated in the same stratum with those of Permian type, or in strata intercalated between beds holding the other fauna; and the Coal Measure fauna becomes by degrees less conspicuous and the Permian types more dominant on passing upward. Mr. Meek maintains that the critical study of the fossils confirms the view published by Hayden and himself in 1858 regarding the rocks of Nebraska and Kansas, that—

> there is in this region a gradual shading off from an Upper Coal Measure to a Permian fauna through a considerable thickness of strata forming a somewhat intermediate group, which is called the "Permo-Carboniferous series;" also there is no defined break between the intermediate series and the Permian above, or the Coal Measures below.[1]

He further adds:

> Under such circumstances it must be evident that all attempts to correlate particular unimportant beds here with minor subdivisions adopted in Europe, where a different state of things obtained, must necessarily fail.

Mr. Meek recognized in his early studies in the section along the Kansas River certain beds containing a fauna which he identified then, in 1858, with the Permian, i. e.: Stratum 10 of the Cottonwood section. Above this were some more or less Barren Measures of 100 to 200 feet thickness, containing gypsum, followed by rocks of unmistakable Cretaceous age. In his early studies the rocks immediately below this unmistakable Cretaceous bed he had, in conjunction with Mr. Hayden, called "Permo-Carboniferous." This paper of 1867 which refers beds in Nebraska to the Upper Coal Measures evidently considered only these "Permo-Carboniferous" rocks of his early classification. The question in dispute was as to whether the rock should be divided, making a Permian system distinctly separate from the Carboniferous below. This Meek positively objected to, his argument being that there was a gradual mingling of the higher faunas with the Upper Coal Measure faunas, and a gradual transition of the deposits from the lower horizon to the upper without break, and without any marked change in paleontology or lithology.

Mr. Marcou,[2] in 1868, wrote that in Nebraska the "Dyas rocks" form the bluffs on the Missouri River in the counties of Nemaha, Otoe, and Cass. The rocks differ from those of the Carboniferous upon which they rest. They consist of clays of red, green, and blue colors; of

[1] Remarks on Professor Geintz's views respecting the Upper Paleozoic rocks and fossils of southeastern Nebraska. By F. B. Meek, Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 338-339.

[2] *On the Dyas in Nebraska*, by Jules Marcou. St. Louis Acad. Sci., Trans., vol. 2, 1868, pp. 562-564.

whitish, gray, and yellowish limestones; of dolomites, and yellow and gray sandstones.

A section of the Dyas taken at Nebraska City is given.

The fossils collected were determined by Mr. Geinitz, of Dresden, Saxony. Many of them are said to be identical with species found in Europe in the Zechstein or Magnesian limestone, as *Serpula planorbites*, *Schizodus Rossicus*, *Allorisma elegans*, etc., and the new species are very nearly allied to Dyassic species of Saxony, Russia, and England. The author speaks also of Carboniferous species, the Brachiopods espe cially, which pass into the Dyas.

F. V. Hayden, in a paper on the Geology of Kansas, reviewing Swallow's Preliminary Report of the Geological Survey of Kansas,[1] objects to Swallow's statement that "the lower Permian strata rests unconformably upon the upper Coal Measures." He questions the accuracy of Swallow's determination of species, in the paper of 1858, and he states that Mr. Swallow has identified fossils coming from a single stratum as equivalent to species of the Carboniferous, Permian, Trias, and Lias, and holds that the community of genuine Carboniferous fossils with those of Permian type indicates that no break, such as unconformity would presume, occurs.

Hayden remarks further that in the few cases of Permian types occurring down in the genuine Coal Measures in Kansas "they appear in particular layers similar to the Permian rocks in composition, and alternating with the other beds containing only carboniferous fossils, much like Barrande's 'Colonies' in the Silurian rocks of Bohemia." He remarks upon the claims to discovery of the Permian in Kansas, and defends Meek, whose announcement of the fact was first mentioned in the records of the Smithsonian Institution, the date being January 19, 1858.

Again Mr. Swallow, remarking on Meek's notes on the Geology of Kansas,[2] goes at some length to show that he first discovered and published as a conclusion the fact that certain rocks were Permian, and makes much point of the fact that Meek claimed only that the fossils sent by Major Hawn "indicated the existence of Permian rocks," and it is stated that at the Baltimore meeting Meek "still doubted whether there really is any Permian system."

This caution on the part of Mr. Meek shows that he saw the true state of the discovery, and maintained that the presence of certain fossils of Permian type did not indicate certainly that there was a representative of the Permian system in Kansas and Nebraska, while Swallow had no doubt that the fossils must indicate the presence of the system. The fact is conspicuous that during this discussion Mr. Meek speaks almost every time of "rocks containing fossils of Permian type," or words to that effect, rather than "Permian rocks,"

[1] Am. Jour. Sci., 1867, 2d ser., vol. 44, pp. 32–40.
[2] Trans. Acad. Sci., St. Louis, vol. 2, pp. 507.

indicating his clear perception of the difference between identity or resemblance of fossils, and absolute correlation of horizon. It may be noted in passing that the solution of this problem, as in other different cases, was by United State geologists; the wide comparative methods of Hayden and Meek led to clearer views than those attained by the local State geologists, Swallow and Shumard, although the latter had closer familiarity with the country and opportunity to get a better view of the local facts.

Swallow reported his section along the south side of Kansas River as follows (according to Meek and Hayden):

Cretaceous	= Cretaceous.
? Triassic Gyps. Sh. Marls, 388 feet	= ? Triassic.
Upper Permian, 141 feet	= "So-called Permian."
Lower Permian, 563 feet	= Permo-Carboniferous.
Carboniferous	= Carboniferous.

Swallow stated that if his lower Permian is not Permian there is no Permian in Kansas, etc. (p. 521), and defended the "unconformability." He stated that Messrs. Marcou, Agassiz, Heer, Geinitz, Shumard, Swallow, Hawn, D'Archiac and others differ from Messrs. Hayden and Meek on the point in question (p. 522). The whole article is controversial and adds little to the settlement of the problem, but brings out clearly the attitudes of the disputants.

The appearance of Permian types in the midst of rocks in which the majority of the forms are typical Coal Measure forms, is taken by Meek and Hayden as evidence of the earlier appearance of Permian types in these regions of America than in those of Europe.

In the final report of the Hayden survey of Nebraska,[1] Mr. F. B. Meek gave a description of the fauna and fully described the correlations of the Permian in Nebraska.

He holds in this paper, in opposition to the view of Geinitz, that the rocks of eastern Nebraska do not belong either to the Lower Cretaceous or to the Permian. The terms Upper, Middle, and Lower Coal Measures are used to express parts of the Coal Measures not clearly divisible by fossils. He does not use the term "Lower Coal Measures" as meaning below the Mountain limestone.[2] He proposes the name "Platte Division" for the upper part of the Coal Measures as exhibited about the mouth of the Platte River, at Bellevue, Plattesmouth, Rock Bluff, and Nebraska City. This he estimates to be two or three hundred feet thick. His Division B outcrops at Nebraska City, Bennett's Mill, and Wyoming; Division C at Nebraska City, and he says that between C and B there is no paleontologic or constant lithologic break. The rocks of the Bellevue section were referred by Marcou to the mountain

[1] Meek, F. B. Report on the Paleontology of Eastern Nebraska with some remarks on the Carboniferous rocks of that district (pp. 81-261) constituting Pt. II of "Final Report of the U. S. Geol. Survey of Nebraska and portions of the adjacent territories made under the direction of the commission of the General Land Office" by F. V. Hayden, U. S. Geologist, Washington, 1872.

[2] Ibid., page 84.

limestone series. The Plattesmouth section Marcou called New Red. The section at Rock Bluff follows that of the Plattesmouth section from 1, 2, 3, upward: this latter section Marcou had referred to the Lower Dyas or New Red. The Cedar Bluff section the author correlated with the part of the Rock Bluff section lying above No. IX. This was called "Upper Permian" or "Dyas" by Marcou and Geinitz. Meek thinks that both Marcou and Geinitz determined the Dyas, in some cases at least, on lithologic instead of paleontologic grounds.

Meek uses the names "Lower Carboniferous," "Millstone grit," and "Coal Measures" to indicate the three grander divisions of the Carboniferous System, with "Permian" and "Dyas" for the still higher member. "Mountain limestone" is used also for Lower Carboniferous. The name "Permo-Carboniferous" is applied by Hayden and Meek to rocks in Kansas, equivalent to Division C at Nebraska City. All the other sections along the Missouri he regards as certainly belonging to the Coal Measures. In Kansas, the division between Permian and Carboniferous is arbitrary, not founded on physical or paleontologic break. Permian rocks in Kansas were first announced in the Transactions of the Albany Institute, vol. 4, 1858. Later investigations led the authors to consider the so-called Permian as merely transitional from the Upper Coal Measures.[1] Meek thinks that facts indicate that these fossils belong in the Carboniferous or Coal Measures, and that there is no abrupt break between the Carboniferous and Permian.

Mr. Meek's Review of Professor Geinitz's paper, 1867, and this Nebraska Report of 1872 practically closed the debate on the Permian problem of Kansas and Nebraska.

Mr. F. B. Meek had been for several years associated with Mr. Hayden in the collection, study, and description of the fossils of these and neighboring Territories. Messrs. Swallow, Shumard and others had examined and reported their identification of fossils from Kansas, which they defined as new species or referred to European species of the Permian age. A collection made by Mr. Marcou had been sent over to Mr. H. B. Geinitz, of Dresden, and there figured and described by him. But Mr. Meek had examined the sections thoroughly in connection with Hayden, and had made an exhaustive study of the fossils, comparing them with European specimens, and studying fully the literature of the whole subject. His paleontological work exhibits a degree of precision of observation, broadness of thought, and thoroughness of study surpassing any of his predecessors in America, and all combined with scrupulous honesty.

Leaving out of the question the dispute as to the real discoverer of the Permian, which provoked considerable discussion and, apparently, ill feeling, the Permian problem was more purely than any that had

[1] See Meek's paper, Am. Jour. Sci., vol. 44, p. 170 and p. 331, in regard to the misidentification of Geinitz.

previously arisen in America a paleontological one. The discovery of some fossils by F. Hawn in Kansas, some of which were sent to G. C. Swallow among Carboniferous species for identification, and others of the same species among Cretaceous forms to Mr. Meek, led to the discovery by both Swallow and Meek of their Permian character. Mr. Swallow appears to have made the first printed announcement of the "Permian rocks," although Mr. Meek had previously announced the identification in private letters, and a few days later Messrs. Meek and Hayden defined the same fossils as "indicating Permian rocks" in papers read at both Albany and Philadelphia.

The fossils in question were identified and described by Swallow, Geinitz, and Meek separately; and the argument for the presence of the Permian system of rocks in Kansas and Nebraska and New Mexico, made by Swallow and seconded by Geinitz, Marcou, and others, was, that in the rocks were found a number of species identical with species characteristic of the Permian rocks of Russia, Germany, and England.

Mr. Meek, supported by Mr. Hayden and others, maintained that the rocks lying above unmistakable upper Coal Measure rocks in this Territory, contained fossils of Permian type, in a few cases showing possible specific identity with European Permian species; but that there was a gradual passage, both lithological and paleontological, from the Coal Measures to the beds containing these Permian types. After obtaining abundant material and giving it exhaustive study, Mr. Meek found the identifications of Swallow, of Marcou, and of Geinitz unsatisfactory. He recognized many species of Permian types, but only a few that he was able to regard as identical with the Permian fossils of Europe. In his report of 1872 he identified from the so-called Permian of the southwest seven genera which had not hitherto been reported below the Permian of Europe, but in the same beds he identified sixteen genera not otherwise known above the Carboniferous. He called attention, however, to the fact, that of the seven genera several are closely related to forms occurring below; secondly, he found several of the species, which are confessedly of Permian type, still lower and in association with unmistakable upper Coal Measure faunas. In his list of the species in question in Nebraska, amounting to one hundred and twenty-two, only thirteen are named which have not been discovered in the Coal Measures of some of the other States. Besides this mingling of species and genera, and their passage upward in such large numbers, he found evidence neither of sudden change in the lithologic character of the strata, nor of stratigraphic break, and his conclusion is, that these rocks belong to the Coal Measures, "and that here we have no abrupt break between the Carboniferous and Permian" (p. 133); "that all these strata under consideration along the Missouri, that have been referred in part to the Mountain limestone, in part to the Permian or Dyas, and in part to the Coal Measures, really belong

to the true Coal Measures," with the exception that the Permo-Carboniferous may be recognized in Bed C of Nebraska City.

This practically closed the debate, although it did not solve the Permian problem. The debate was ended, because the evidence was perfectly clear that the rocks and fauna referred to the Permian, were separable from those below by no stratigraphic or paleontologic break, and petrographically only by differences such as are recognized in two formations almost anywhere in the geologic series. The question whether they be called "Permian" or "Coal Measures" would be settled one way by those who considered it of chief importance to establish uniformity in the geological nomenclature of America and Russia; and it would be settled the other way by those who sought to establish a natural classification of American rocks.

The application of the name "Permian" to these rocks was purely artificial, and as was stated several times during the debate, the classification thus implied would not have been thought of if the rocks of this region alone had been considered.

The general question as to whether the Permian shall be ranked as a system separate from the Carboniferous, is still an open one, and bids fair to continue so until a natural method of classification for the time-scale be devised, which shall be independent of the lithologic character of the rocks.

The correlation of the Permian in the Acadian and Appalachian provinces is a distinct problem from that in the Mississippian province. In the former plants enter into the question, and as I have previously stated the correlative value of plants is not attempted in the present essay.

In chapter IV the Appalachian representatives of the Permian are considered.

The correlations of the Upper Carboniferous and Permian of the Acadian province are discussed in Chapter XII, but a few words may here be said regarding Dr. J. W. Dawson's correlations in the "Acadian Geology," second edition, 1868.

Dr. Dawson considered the Permian as absent in the Acadian district. The Trias rests unconformably upon the Upper Carboniferous, and the author held that the time represented by the Permian in Europe was a period of disturbance in Acadia, with land extending over the greater part of the region.

The limestones of Colchester and Hants contain some fossils which were regarded by Davidson as allied, if not identical with Permian fossils[1] and Mr. Meek suggested that these may have constituted a colony, in the Barrandian sense, of Permian forms in the Carboniferous age. The author, however, thought the deposits undoubtedly Carboniferous, and Lower Carboniferous, but that they assume some of the

[1] Pp. 278-285.

modifications more characteristic of the true Permian faunas of Europe.[1] In regard to the conditions of deposition, he interpreted the series as follows:[2] Marine limestones indicate lowest depression; coal beds were formed during the greatest elevation, and the condition of Millstone grit and the newer coal formations was intermediate between these two. Tidal currents were recognized in the Carboniferous, cutting out channels called "tidal channels."[3] The author also recognized that Devonian and Silurian rocks were above the water during the deposition of the rocks of the Coal Measures of Nova Scotia, so that the coal deposits are more or less separated from each other.

The flora was regarded as identical throughout the whole Middle Coal Measures, and the Lower, Middle, and Upper may be distinguished by their plants. Dawson also held that the flora of the Lower Coal Measures of Nova Scotia is wholly Carboniferous, and that the flora of the Chemung, Vergent, and Ponent, IX and X, of Lesley, is decidedly Devonian.

The author recognized, not 25,000 feet for Nova Scotia Coal Measures, but Logan's measure of 15,570 feet for the Joggins, and for the Middle Coal Measures, 1,000. He mentioned the fact that in England it is the usage to apply the term Lower Coal Measures to the lower part of what he called the Middle Coal formation, that is, above the Millstone grit. He quoted Geinitz in identifying the divisions of the coal formations by plants. His Lower Coal formation is the Lycopodiaceous Zone or Culm of Europe; his Middle Coal formation is the Sigillaria and Stigmaria Zone; the Upper Coal formation is the Zone of Calamites of Geinitz.

Mr. C. A. White wrote in 1874 that Dr. L. G. De Koninck had identified many of the species from the Coal Measures of Springfield, Illinois, with Lower Carboniferous species of Europe, and Geinitz had identified species found in the Upper Carboniferous of Nebraska as Permian. The mingling of faunas thus indicated, the author held, is due to the fact that while the region in which true Coal Measures were being deposited were little invaded by the seas during the whole Carboniferous period, America was occupied in some places by the sea, which fact accounts for the wide distribution of marine faunas as compared with those of Europe. Chronological development is also proved by the similarity of the floras of the two countries, as has been pointed out by Dr. Newberry and Mr. Lesquereux.

The next four papers give additional information upon the Permian and Permo-Carboniferous formations of Kansas and Nebraska.[4]

Coal belonging to the Lower Coal Measures is found in marketable quantities in Osage County. It is well exposed on the southern side of Neosho Valley, running through Miami County. Upper Coal Meas-

[1] Pp. 283–285.
[2] P. 133.
[3] *P. 125.*
[4] *Broadhead, G. C.:* The Carboniferous rocks of southeastern Kansas. Am. Jour. Sci., 3d ser., 1881, *vol. 22, pp. 55–57.*

ures also occur west of the Verdigris River, and are soon covered by Permian rocks. The western limit of the coal is along the line between Greenwood and Woodson Counties.

The Permian rocks are found along a ridge running through Cowley and Chautauqua Counties and southern Kansas, which is known as the "Flint Hills," having an elevation of 1,600 feet above sea level. The Permian rocks rest conformably on the Carboniferous, rendering it difficult to draw any absolute line between them. It is estimated that the Permian has a total thickness of 1,500 feet in southern Kansas, while the Upper Coal Measures are about 500 feet in thickness, consisting mainly of sandstones and limestones.

In a second paper[1] the same author further reported: The valley traversed by the Neosho River is in the lower part of the Middle Coal Measures, which are only productive in the southern extension, but northwardly, in Osage County, coal is mined belonging to the Lower Measures, showing "an uplift of Lower [Middle?] Coal Measures, flanked to the east and west, as we proceed northwardly, by the Upper Coal Measures."

In Neosho, Wilson, Labette, and Montgomery Counties we find sandstones in even, flag-like layers, 50 feet thick at Thayer, Neosho County, where coal is extensively worked. Many fossil plants are found in the coal, including *Calamites*, *Lepidodendron*, etc.

In Johnson and Wyandotte Counties limestones and calcareous shale beds of the Upper Coal Measures with molluscan remains are recognized, corresponding with similar beds in Cass and Jackson Counties, Missouri; and at Eudora, Douglas County, is found the Plattsburg limestone of Missouri, containing many beautiful Bryozoans. Above this is a gray limestone abounding in *Syntrielasma hemiplicata*, its interior lined with clear crystallized calcite. A little higher is a limestone containing *Fusulina cylindrica*.

The Productive Coal Measures are found in the eastern tier of counties south of Miami County and include valuable coal beds.

In Miami and Anderson Counties the upper limestone is surmounted by an oolitic limestone. In Woodson and Greenwood and the northeast part of Elk Counties there are about 50 feet of coarse brown sandstone, almost without fossils, with only occasional fragments of fucoids and *Cordaites*.

In the southeast, near the line of Cowley and Chautauqua Counties, are the "Flint Hills," so called from the numerous fragments of flint strewn over the surface. These hills include the Permian rocks of Kansas, reaching a thickness of about 500 feet. A section of the rocks is given, showing 19 divisions of strata, the upper 12 of which are of Permian type, and the remaining 7 belong to the Upper Coal Measures. Several of the Permian layers abound in *Fusulina*. They are mostly

[1] The Carboniferous rocks of eastern Kansas, by G. C. Broadhead. St. Louis Acad. Sci., Trans., vol. 4, pp. 481-493, 1882.

limestone, shaly, magnesian, or cherty, while the lower layers are more arenaceous.

The highest coal series is seen in Greenwood County, its position being about the base of the Permian or top of the true Upper Coal Measures.

One thousand five hundred feet of Permian beds in southern Kansas are assumed. In this region it is the newest rock below the Quaternary. It rests conformably on the Coal Measures, and there is no decided line of separation between the two.

The Permo-Carboniferous was identified in southern Kansas by Mr. F. W. Cragin, in 1885.[1]

The most interesting feature of this region is the occurrence of a large stratum of gypsum. This is considered as a Permo-Carboniferous deposit. This horizon is entirely different from that of the gypsiferous deposits represented in Barber and eastern Comanche Counties, which is considered as Mesozoic.

In 1886, commenting upon the Carboniferous and Permian rocks of Nebraska, in the American Naturalist,[2] L. E. Hicks describes a series of limestones and marls in Nebraska evidently distinct from the Coal Measures. They are blue, yellow, and buff in color, and have a total thickness of about 200 feet The dip at Big Blue River from Beatrice to Homesville is southeast; at Indian Creek it is west. Of the 123 species described by Meek from the Coal Measures, not more than 10 or 14 entered into the Permian. The author uses the term "Permian" provisionally for these limestones and marls.

[1] Cragin, F. W.: Notes on the geology of southern Kansas. Washburn College Lab. Bull., vol. 1, 1885, pp. 85–91 and 112.

[2] Hicks, L. E.: The Permian in Nebraska. Am. Nat., vol. 20, 1886, pp. 881–883; abstract in Am. Assoc. Proc., vol. 35, pp. 216, 217.

CHAPTER X.

DEVONIAN AND CARBONIFEROUS CORRELATIONS IN THE WESTERN AND NORTHERN PROVINCES.

In the Rocky Mountain region and the western part of the United States and in British North America are large tracts of territory which have been roughly surveyed, and in places with sufficient detail for the correlation of the grand geological divisions; but in little of this region have the details of either the stratigraphy or the paleontology been worked out with sufficient minuteness to permit of fuller correlations than with the systems of other parts of the world or their upper or lower parts without precise reference to limits. The literature concerning these correlations will be reviewed chronologically in the present chapter, beginning with the Hayden reports of 1868, prior to which date little of interest for this essay can be gleaned.

In 1868, Mr. F. V. Hayden, in the American Journal of Science,[1] gave a brief report of the results of his examinations of the geology of the Rocky Mountains, in which some generalizations are made based upon his wide knowledge of the region. The object of this paper was to show that quite marked lithological and paleontological changes occur in the rocks of the Rocky Mountains as we proceed from the north southward. The nucleus of the mountains at any one point along the eastern range is composed of massive granite rocks; then follows a series of metamorphic rocks. Upon these the Silurian period is represented by the Potsdam sandstone; the Devonian is wanting; then follow the Carboniferous, Red Beds, Jurassic, Cretaceous, Tertiary.

There is no marked change in the Tertiary from the North to the Arkansas River, but many changes were observed in the Cretaceous. The Jurassic thins out to the southward, as do the Red Beds or supposed Triassic. In the far north the Carboniferous rocks are often 500 to 1,500 feet in thickness, and from 500 to 1,000 feet thick as far south as the Red Buttes, and are quite distinct from the Red Beds, but the latter prevail farther south. The Carboniferous rocks become of a red arenaceous character, with a few layers, from two to ten feet in thickness, of a whitish or yellowish limestone. Dr. Hayden could find no break to separate the Red Beds from the Carboniferous, and concluded they might possibly all be of that formation. The Potsdam sandstone

[1] Hayden, F. V.: Remarks on the geological formations along the eastern margins of the Rocky Mountains. Am. Jour. Sci., vol. 45, 1868, pp. 322-326.

thins out entirely south of the Red Buttes on the North Platte. The Carboniferous seemed to rest directly, though not conformably, upon the metamorphic rocks.

The conclusions drawn from the observations made were that all the formations of the west undergo more or less change in both their mineral and fossil contents in their extension toward the west and south, and that the Potsdam sandstone and Jurassic beds present more remarkable changes than any of the others.

In 1868 Mr. F. B. Meek examined several lots of fossils collected in British America, some of which he found to be new; these he described and figured. Others he identified with already known fossils, and by these correlated the formations in which they occurred with formations in other parts of the country. The localities are on the Clearwater River, near its mouth into the Athabasca; on Laird's River, near Fort Resolution; on Slave Lake, and several localities along the Mackenzie River Valley to old Fort Good Hope, and one locality on Porcupine River.

From the study of the fossils the following conclusions were reached: That along the Mackenzie River and its tributaries, between the Clearwater and the Arctic Ocean, "no Carboniferous or characteristic Silurian formations are seen," and that there is "a continuous stretch of Devonian rocks, mainly of the age of the Hamilton group, extending from Rock Island, Ill., in a northwesterly direction to the Arctic Ocean, a distance in a right line of nearly 2,500 geographical miles."

The great general similarity with frequent specific identity in the faunas from the extreme ends of this line, the author considers, "strongly corroborates the generally accepted opinion that climatic conditions, if not uniform over the whole world, were at least little, if at all, influenced by differences of latitude during paleozoic epochs."[1]

F. H. Bradley reported in 1872[2] the discovery of a few small trilobites of Quebec group age, in the base of the mass of limestones overlying the central granites of the Teton Range in Idaho. These limestones continue up to the typical Carboniferous. The Quebec group is about 400 feet thick, partly argillaceous, blue, and mostly pebbly. Above this group are 600 feet of a magnesian limestone, drab to buff color, which Bradley correlated with the "cliff" limestone of the Mississippi Valley; and over this he found the true Carboniferous.

In August, 1872, Professor Tenney[3] found corals in the Wahsatch Mountains, southeast of Salt Lake City, in a dark bluish limestone, nine or ten thousand feet above the sea. His own opinion that the corals were Devonian was confirmed by R. P. Whitfield, who referred

[1] Meek, B. F.: Remarks on the geology of the valley of Mackenzie River, with figures and descriptions of fossils, etc. Chicago Acad. Sci., Trans., vol. 1, 1869, pp. 61–114, and plates.

[2] Bradley, F. H.: On Quebec and Carboniferous rocks in the Teton Range. Am. Jour. Sci., 3d series, vol. 4, 1872, pp. 230, 231.

[3] Tenney, Sanborne: On Devonian fossils in the Wahsatch Mountains. Am. Jour. Sci., 3d series, *vol. 5, 1873, pp.* 139, 140.

them to *Zaphrentis* and *Syringopora*, one species of the latter and two of the former. They were the first fossils of the Upper Helderberg period brought to light from the range of the Wahsatch.

Mr. James Richardson,[1] in 1874, reported a few fossils from, and gave a section, of Ballinac Island, consisting mainly of epidotic rocks, diorite, and reddish limestones, carrying well preserved fossils of encrinites, corals, and brachiopods. He considered that the "age of these rocks is either Carboniferous or Permian, most probably the former."

In the third volume of the report upon the geographical and geological explorations and survey west of the 100th meridian, Mr. G. K. Gilbert reported identifications of sections made in the cañons and other regions west of the Rocky Mountains.[2]

In southern Nevada, the rocks of the Spring Mountain Range consist of fossiliferous limestones, with bands of sandstone of Carboniferous age. The strata seem to be conformable throughout the whole vertical range. Again, in the Black Hills, Arizona, sedimentary rocks of Carboniferous aspect were seen overlying a crystalline series similar to those noted in Bowlder Cañon. In Arizona the plateaus consist of Carboniferous limestone (Aubrey limestone, Red Wall limestone). The adjacent ranges show the Tonto sandstones. The exploration of the Colorado plateau system showed that the rocks which compose it range from Eocene Tertiary to the Tonto group, which underlies the Carboniferous rock of the Grand Cañon of Colorado. The next bench below that, named by Powell the "Shinarump Mesa," is capped by a Carboniferous limestone extending from Paria Creek southwest to Aubrey Valley. Through this section the Grand and Marble Cañons have cut their way. After giving a general topographical description, and at the same time referring to the geologic age of the rocks in general, the author adds a series of twenty-one vertical sections, indicating physical characters and thickness, together with fossil remains. These sections are finally correlated in tabular forms, thus giving a view of the whole vertical range. Of the twenty-one sections given, Upper Carboniferous rocks occur in the following:

SECTION V. *Jacob's Pool.*—The rocks consisting of massive sandstones, alternating with gypsiferous cherty clay-shale and chocolate shale and cherty limestones, containing *Productus Meekella, Pseudomonotis, Hemipronitis, Aviculopecten*, etc. Total thickness, 3,750 feet.

SECTION VI. *Kanab Creek.*—Physical character of rocks similar to those of Section V; additional fossils in cherty limestone. *Fenestella* (?) *Spirifera lineatus, Orthis, Chonetes*, etc. Total thickness, 4,200 feet.

SECTION VII. *Grand Cañon.*—Rocks similar to those of Section VI. Total thickness, 4,825 feet.

SECTION VIII. *Aubrey Cliff*, 15 miles southeast of Bill Williams Mountain, Arizona.—Rocks, limestones and yellow-red friable sandstones. Total thickness, 2,100 feet.

[1] Richardson, James: Report on geological explorations in British Columbia. Geol. Survey Canada; Report of Progress for 1873–'74. 1874, pp. 94–102.

[2] Report on the geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871 and 1872, by G. K. Gilbert, A. M., pp. 17–187 of report upon the geographical and geological explorations and survey west of the one hundredth meridian. 1875.

SECTION IX. *Aubrey Cliff, at Cañon Creek, north Arizona.*—Rocks consist of alternating sandstones, limestones, and shales. Total thickness, 2,360 feet.

SECTION X. *Carrizo Creek, north Arizona.*—Rocks consist of yellow sandstone and dark gray fossiliferous limestones. Total thickness, 1,420 feet.

SECTION XI. *North from and near Camp Apache, Arizona.*—Physical characters similar. Total thickness, 2,260 feet.

SECTION XII. *Spring Mountain, Nevada.*—Total thickness, 2,395 feet.

SECTION XIII. *Ophir City.*—Fossils numerous. Thickness, 1,975 feet.

The occurrence of Lower Carboniferous and Devonian rocks is somewhat questionable, except at Ophir City. The author also reported the discovery at the top of the "Aubrey limestone" of a few fossils suggesting the Permo-Carboniferous of the Mississippi Valley.

The Carboniferous formations of northern Arizona and in the Grand Cañon were classified as follows:

	Feet.
Aubrey limestone—Aubrey Valley, north Arizona	820
Aubrey sandstone—(no fossils except in an intercalated limestone below the middle—a few Coal Measure fossils)	1,000
Red Wall limestone—named from the red appearance of escarpments in Grand Cañon	2,500

The above names were proposed by Mr. Gilbert and Mr. Marvine.

The middle of the Red Wall limestone furnished fossils which Mr. Meek doubtfully referred to Lower Carboniferous. The upper portion, by its fossils, was correlated with the Coal Measures.

It is stated that Mr. Marcou, in the Geology of North America, had called the Aubrey limestone "Permian," the sandstone "Coal Measures," and the Red Wall limestone "Carboniferous limestone or Mountain limestone." Mr. Gilbert referred to the local character of the sedimentation in the Grand Cañon; that 75 miles westward he was unable to correlate the series in detail. Mr. A. R. Marvine, in the same volume, reported the identification of beds between the Black Mesa and the Sunset tanks as "? Permo-Carboniferous."[1]

Mr. A. J. Brown reported in Pancake Mountain a vein of coal which was regarded by the author as probably the first carboniferous coal discovered west of the Rocky Mountains, unless some of the Utah coals belong to this age. This vein is worked at the north end of this range of hills, about 14 miles west of Hamilton. It has a thickness of from 5 to 6 feet, with a dip of 40° to the west.[2]

In 1876, Mr. J. W. Powell presented a classification of the sedimentary rocks of the Plateau Provinces.[3]

In this classification the Aubrey group of Mr. Gilbert is divided into the upper and the lower Aubrey groups. The upper Aubrey group consists of sandstone and cherty limestone of 1,000 feet thickness, seen

[1] Report on the geology of route from St. George, Utah, to Gila River, Arizona, examined in 1871, by A. R. Marvine, pp. 189–225.

[2] Carboniferous coal in Nevada, by A. J. Brown, Trans. Am. Inst. Mining Eng., vol. 3, 1875, pp. 31–33.

[3] Department of the Interior. U. S. Geol. and Geogr. survey of the Territories, 2d division. J. W. Powell, geologist in charge. Report on the geology of the eastern portion of the Uinta Mountains *and a region of country* adjacent thereto, by J. W. Powell. Washington. 1876.

along Marble, Cataract, Grand, Green, Horseshoe, and Split Mountain Cañons. In its upper part it is "Bellerophon limestone," and in its lower part the "Tampa sandstone."

The lower Aubrey group consists of massive and shaly limestones and sandstones 1,000 feet in thickness.

The "Red Wall group," which is most conspicuous in the Grand Cañon and those adjacent, has a thickness of 2,000 feet, and consists of two distinct members, the upper part of massive saccharoid limestones, the lower of indurated limestones, very irregularly stratified. This division was also recognized in the Uinta Mountains. Below this is a series of sandstones and shales, termed the "Lodore group," and supposed by the author to be the equivalent in the Uinta Mountains of the Tonto group in the Grand Cañon. It forms the base of the Carboniferous formation, but is considered by Mr. Gilbert as probably of Silurian age. The total thickness of the Carboniferous series amounts to 4,460 feet. It rests upon the "Uinta group," which is not seen at Cataract Cañon, but is well displayed in the Uinta Mountains. This formation in turn overlies uncomformably the "Red Creek quartzites," which are believed to be of Eozoic age.

In his geological report on the Santa Fé Expedition, J. S. Newberry reported Carboniferous, Permo-Carboniferous, and true Permian.[4]

The "upper and lower Magnesian limestone" of his report, seen near Cottonwood Creek, he correlated with C and B of the Nebraska City formations, as described by Marcou and Swallow. His correlation was substantially as follows:

Nebraska City.	Swallow.	Meek & Hayden.	Newberry.
C.	Upper Perm.	Permian.	Upper Magnesian limestone.
B.	Lower Perm.	Permo-Carb.	Lower Magnesian limestone.

Mr. Clarence King[1] gave a preliminary account of the results of the survey along the fortieth parallel in 1876.

The area described in this paper extends from the eastern base of the Rocky Mountains to the eastern boundary of California, along the fortieth and forty-first parallels, and is a little over 100 miles from north to south. The object of the paper is "to announce the stratigraphical divisions established in the field and their relation to the Paleozoic subdivisions as established in New York and in the Mississippi Basin."

In the region of the Rocky Mountains the entire Paleozoic series, including Coal Measure beds and strata bearing Potsdam fossils, is found within a section of from 900 to 1,200 feet thickness, the whole entirely conformable and resting discordantly upon the Archean rocks. Going westward the series expands from 1,000 to 32,000 feet. The Rocky Mountain region represented Archean islands and shallows, around and over which sediments were deposited, while to the west-

[4] Report of the Exploring Expedition from Santa Fé, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the West in 1859, under command of Capt. J. N. Macomb, 4°, pp. 9–143. Map and plates. Washington. 1876.

[1] King, Clarence: Paleozoic subdivisions on the 40th parallel. Am. Jour. Sci., 3d ser., vol. XI, 1876, pp. 475–482.

ward the Paleozoic ocean deepened over a broad basin, which probably continued to a great depth until it reached the western shore, in longitude 117° 30′. It is a striking fact that no unconformity has been found in the exposures studied between the members of the series, from the Primordial to the summit of the Coal Measures.

The author remarks that the key to the subdivision of the whole Paleozoic is obtained in the Wasatch Range, where he observed a single section, of about 30,000 feet thickness, of conformable rocks, extending from the Permo-Carboniferous strata, conformably underlying the red sandstones of the Trias, down to low exposures of the Cambrian, and he notes in their order, from the base of the Cambrian upward, the important stratigraphic divisions, with their position in the New York scheme.

The lowest division of the series is composed of three prominent terranes, the lowest a series of siliceous schists and argillites, from 800 to 1,000 feet in thickness; next is a series of quartzite and quartzofeldsitic strata, with limited beds of slate interspersed through it, and dark micaceous zones near the top, the whole in Cottonwood Cañon reaching a thickness of 12,000 feet; the third terrane is a narrow zone of variable argillites, calcareous shales, and thin, slightly siliceous limestones, whose extreme thickness is 75 feet. The only fossils found in this division occur in the shaly zone and are of Primordial type.

The author includes the uppermost beds in the Potsdam epoch of the Primordial period, and considers the whole underlying conformable series as Cambrian down to the Archean. This Cambrian formation varies in thickness, not reaching an exposure of over 100 feet at the extreme east of the field, while in middle Nevada the uppermost thin, shaly member of this terrane in the Wasatch Range is an immense body of dark limestone, 3,000 feet in thickness, carrying Primordial fossils throughout. A list of fossils obtained from the Cambrian series is given.

Above the shales of the Cambrian is a bed of limestone, having a maximum thickness of 2,000 feet in the Wasatch, which the author calls the "Ute limestone," and which has yielded only fossils of the Quebec group. In western Nevada the calcareous shales of the Potsdam and the Quebec limestone have greatly thickened, and represent from 4,000 to 5,000 feet of continuous limestone, yielding fossils of the Lower Helderberg, Niagara, Quebec, and Primordial.

Overlying the Ute limestone is a quartzite from 1,000 to 1,500 feet thick, called by the author the "Ogden quartzite," from its exposure in the Ogden Cañon; it is seen in western Nevada between the Upper and Lower Helderberg horizons, and is included provisionally within the Devonian system, being considered as the probable equivalent of the Scholarie and Cauda-galli grits.

Next above is the "Wasatch limestone," reaching 7,000 feet in thickness in the Wasatch and over 8,000 in middle Nevada. Its lower

1,200 or 1,400 feet belong to the Devonian, having fossils of the Upper Helderberg and Chemung groups. The fossils obtained from the Upper Helderberg horizon are mentioned, and those also from the upper members of the Devonian. The Genesee and Chemung faunas of the Wahsatch limestone are followed by beds whose forms closely resemble those of the Waverly group, but Messrs. Hall and Whitfield considered them Upper Devonian. A gap of barren limestones occurs between the Waverly and this fossiliferous zone, so that the thickness of the Waverly is not definitely known, but in the Oquirrh Range the combined thickness of the Waverly and Subcarboniferous can not be less than 1,000 feet. The remaining 4,000 feet of the Wahsatch limestone contain at intervals beds with distinct Coal Measure forms. The Wahsatch limestone, therefore, represents 4,000 to 4,500 feet of Coal Measures, 1,000 to 1,200 feet of Subcarboniferous and Waverly [Mississippian], and 1,000 to 1,400 feet of Devonian.

Above the Wasatch limestone is found a bed of siliceous material called the "Weber quartzite," from its typical exposure in the Weber Cañon. It is about 6,000 feet in thickness, with a few red sandstones at the base, occasional limited fine beds of shale interspersed at three or four different horizons, and varied by thin sheets of conglomerate and rounded quartz pebbles. It is referred to the middle Coal Measures, though no fossils are found in it in this locality. Six thousand feet is its minimum thickness; it reaches 9,000 to 10,000 feet in the Oquirrh. The great terrane of sandstones, with intercalated shales and conglomerates, forming the body of the Uinta Range, is referred to this member of the series.

Overlying it is a terrane of about 2,000 to 2,500 feet of limestones, chert beds, calcareous and argillaceous shales, and beds of calcareous sandstones and arenaceous limestones, a very variable series, and throughout carrying Coal Measure forms; and above this is another variable terrane of argillaceous and calcareous shales and mud rocks, with limited beds of limestone and sandstone, containing many ripple marks. It contains forms referred by Meek and Hall and Whitfield to the Permo-Carboniferous. Its maximum thickness is 500 feet.

"Aside from the intimation of a local shallowing at the close of the Wahsatch limestone in western Nevada, the evidences are all of deep-water deposits till near the close of the Upper Coal Measure series, when ripple-marked shales make their appearance, and the Permian depositions thereafter seem all to be of a shoal-water character."[1]

In the year 1878 Mr. Clarence King's[2] first volume of the U. S. Geological Exploration of the Fortieth Parallel was published.

[1] The details of this series of correlations is given in Volumes I, II, and IV of the reports of the "United States Geological Exploration of the 40th parallel, Clarence King, Geologist in charge, Washington, 1877 and 1878."

Vol. I. Systematic Geology, by Clarence King.

Vol. II. Descriptive Geology, by Arnold Hague and S. F. Emmons.

Vol. IV. Part I, Paleontology, by F. B. Meek; Part II, Paleontology, by James Hall and R. P. Whitfield.

[2] "*Systematic Geology,*" *by Clarence King*, U. S. Geologist, Washington, 1878.

A chart of "Paleozoic subdivisions; Wahsatch and Middle Nevada," is given on page 248, expressing the nomenclature used and the correlation.

Above the Silurian formations the sections were as follows:

Wahsatch section.	Middle Nevada section.
Carboniferous, 15,000 feet..	Permian, 650 feet, clays, marls, and limestones..(absent)
	Upper Coal Measures, limestone.....2,000 feet
	Weber quartzite.....6,000 feet
	Wahsatch limestone.....7600 feet
Devonian, 2,000 feet.....	Waverly. Ogden quartzite, 1,000 feet

Fossils were collected from which correlations were made of Devonian, including Upper Helderberg, Chemung, and Genesee horizons in the lower Wahsatch limestone, of Waverly faunas above, and then of Subcarboniferous forms in the lower 2,200 feet. The upper 4,500 feet were characterized by abundant Coal Measure forms. The Weber quartzite separates the lower from the upper Coal Measure limestone. The upper Coal Measure limestone contains some of the same species seen in the upper part of the Wahsatch limestone, but over 20 species were named that did not occur below the quartzite. "In the Wahsatch and Uinta exposures a series of argillaceous and calcareous shales, with muddy marls, overlying the upper Coal Measure limestones" reached the thickness of 650 feet and carried "from summit to base a characteristic Permo-Carboniferous fauna."[1] The species are Lamellibranchs, several of them identical with Meek's species described in the faunas of Nebraska and Kansas.

In 1879, at a meeting of the Philosophical Society of Washington, Capt. C. E. Dutton announced the discovery of the Permian system in southern Utah.[2]

The discovery was made by C. D. Walcott of well marked Permian fossils in the red sandstone beds at Kanab, southern Utah. The beds were known before, but had not yielded fossils. Heretofore they were regarded as Triassic. In the author's opinion this established the Permian age for the lower part of the red beds of Colorado, Wyoming, the Uinta Mountains, and New Mexico, the variegated marls of Newberry in Arizona and New Mexico, and the Shinarump of Powell (pp. 6, 7).

Mr. C. D. Walcott published an account of the facts in 1880.[3]

[1] Page 245.

[2] On the Permian formation of North America (abstract), Washington Phil. Soc. Bull., vol. 3, pp. 67, 68; Smithsonian Miscellaneous Collection, vol. 20.

[3] The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, pp. 221–225.

The following table exhibits the essential facts of the paper:[1]

Shinarump conglomerate.		
Unconformity.		
Permian	Upper gypsiferous and arenaceous shales, marls, and limestones	710 feet
	Unconformity.	
	Lower, chiefly massive limestones="Permo-Carboniferous" of Gilbert	145 feet
Unconformity.		
Upper Aubrey limestone		835 feet
Lower Aubrey sandstone		1,455 feet
Red Wall limestone		970 feet
Unconformity.		
Devonian, sandstone and impure limestone		100 feet

Mr. G. M. Dawson[2] in 1879 reported: "Between Kamloops and Little Shuswap Lake, on both sides of the South Thompson, rocks belonging to the Nicola series, with older rocks referable to the Cache Creek group, occur." The occurrence of *Fusulina* in the Nicola limestone series proves it to be of Carboniferous age. This same fossil, along with Foraminifera, named by the author *Loftusia Columbia*, was found in the limestones of Marble Cañon, situated in the section between Lillovet and Bonaparte River.

Mr. Jacob Boll[3] in 1880 reported upon the geology of Texas, saying that the rocks examined appear to be of Permian age, judging by the fossil contents. After giving a description of their mineralogical characters he notes that no coal deposits have yet been found in the Permian. In the south of the Permian region genuine coal is found belonging to the Coal Measures.

Mr. C. D. Walcott[4] in 1880 gave account of his correlations in the Kanab Valley, Arizona, as follows:

The Permian rocks are unconformable with the Shinarump Conglomerate, which is considered as the base of the Mesozoic group. They consist mainly of gypsiferous and arenaceous shales, marls, and limestones, 710 feet in thickness, called Upper Permian, and 145 feet of Lower Permian, consisting chiefly of massive limestones. The Permo-Carboniferous of Mr. Gilbert is the equivalent of the author's (L. P.) "Lower Permian."

The Carboniferous rocks here have a total thickness of 3,260 feet, and are subdivided into three parts, the Upper Aubrey beds (835 feet), the Lower Aubrey (1,455 feet), and the Red Wall limestone (970 feet). The latter consists mainly of red sandstones, calciferous sandrock, and limestones interstratified with layers of chert.

The Devonian beds are made up of sandstones and impure limestones, having a thickness of 100 feet, and are slightly unconformable with the overlying rocks.

Mr. C. A. White,[5] during the year 1880, contributed two papers re-

[1] Am. Jour. Sci., 3d ser., vol. 20, page 223.

[2] Dawson, G. M.: Report on explorations in the southern portion of the interior of British Columbia. Geol. Survey Canada; Report of Progress, 1877–'78, 1879, pp. 1*b*–173*b*.

[3] Boll, Jacob: Geological examinations in Texas. Am. Nat., vol. 14, 1880, pp. 684–686.

[4] Walcott, C. D.: The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 221–225.

[5] Remarks upon certain Carboniferous fossils from Colorado, Arizona, Idaho, Utah, and Wyoming, and certain Cretaceous corals from Colorado, together with descriptions of new forms, by C. A. White U. S. Geological and Geographical Survey of the Territories, F. V. Hayden, Bull. vol. 5, 1880, pp. 209, 221.

The subject of the Permian formation in North America. (Abstract.) Washington Phil. Soc. Bull., vol. 3, pp. 104–105. By *C. A. White*.

garding these correlations. In the first paper he reported the correlation of "Subcarboniferous, Carboniferous, and ? Permian" by the fossils examined, but he thinks "there are no true Permian strata in Colorado, Utah, Wyoming, or Idaho, but may be farther west." In the second paper he accepted the evidence of the fossils ("*Bakewellia*," etc.) reported by Mr. Walcott from the red beds above the Aubrey limestone as proving them to be "correlatives of the Permian of Europe." "It does not follow that the periods were strictly coeval in the two continents."

Mr. Gilbert, in the Philosophical Society,[1] stated that "the contact of these beds is frequently, and perhaps generally, unconformable in the vicinity of the locality where the fossils are found, but there was no such break separating them from the Trias beds above." And Mr. J. W. Powell, discussing the same paper, remarked that "the stratigraphic evidence, as well as the fossils, confirmed the correlation of the beds as Permian from the Great Basin of Uinta and Arizona." The fossils found were substantially the same as those found by Mr. King.

In 1880 Mr. E. T. Cox[2] reported that the rocks about Tucson contain fossils of Devonian, Subcarboniferous, and Coal Measure species. The rocks are semicrystalline, coarse grained, and easily decomposed.

The most exhaustive study of the Paleozoic formations of the Great Basin province of the west was made by Mr. Arnold Hague in the Eureka district, an abstract of the report upon which was published in 1883.[3]

All the identification of fossils for this report were made by Mr. Charles D. Walcott, who prepared a report in 1882 to go with Mr. Hague's report, but subsequently enlarged it, adding results of his study of new collections and of the sections themselves, and published the final results as an exhaustive memoir in 1884.[4]

This Eureka section, Nevada, as reported by Mr. Hague, is 30,000 feet thick, made up of 7,700 feet Cambrian, 5,000 feet of Silurian, 8,000 feet of Devonian, and 9,300 feet of Carboniferous.

The nomenclature and classification adopted for the Upper Paleozoic is as follows:

		Feet.
Carboniferous	Upper Coal Measures (limestone)	500
	Weber Conglomerate	2,000
	Lower Coal Measures (limestone)	3,800
	Diamond Peak quartzite	3,000
Devonian	White Pine shale	2,000
	Nevada limestone	6,000
Silurian	Lone Mountain limestone, etc	1,800

[1] "Permian-Carboniferous overlap in the west," (abstract), by G. K. Gilbert. Washington Phil. Soc. Bull., vol. 3, pp. 105–106.

[2] Cox, E. T.: The Geology of Southern Arizona. Am. Nat., vol. 14, 1880, pp. 541, 542.

[3] Abstract of Report on the Geology of the Eureka District, by Arnold Hague. 3d Ann. Rept. of the U. S. Geol. Survey for 1881–'82, 1883, by J. W. Powell, Director, pp. 241–288.

[4] Monographs of the U. S. Geol. Survey, vol. 8, 1884. Paleontology of the Eureka District, by Charles Doolittle Walcott, pp. 1–298, Pls. I–XXIV.

The boundary line between the Silurian and Devonian is said to be arbitrarily drawn, as the passage from the lower to the upper limestone is gradual, "with poorly defined lithological distinctions, and without, as yet, any paleontological evidences" for making sharp distinctions.[1] But below the Lone Mountain limestone (Silurian) is a plane of unconformity.

The Nevada limestone, although so thick (6,000 feet), offers no lithologic or paleontologic evidence by which to divide it sharply into subdivisions. The fauna is rich and often well preserved, and contains species of the Upper Helderberg, Hamilton, and Chemung formations of New York. While there is recognized a lower and upper fauna, many of the species show a remarkable range, and some of them "have reversed their relative positions in the group as they have been known heretofore. Among the Brachiopods *Orthis tulliensis*, of the Tully limestone of New York State, is found at the summit of the Devonian limestone, and *Orthis impressa*, a Chemung species of New York, at the base, associated with eastern Upper Helderberg limestone species."[2]

The White Pine shale, in the White Pine district, carries a fauna which combines species ranging from Middle Devonian to Lower Carboniferous in the east. The Devonian fauna described contains 102 genera and 225 species, and 94 genera and 79 species of these are identified as common to Nevada and New York. Two species described from the Mackenzie River Basin were identified among the Eureka Devonian fossils. The Carboniferous age of the Diamond Peak Quartzite is determined by the occurrence of a Carboniferous *Productus* in an intercalated limestone stratum 500 feet from its base. The lower limestone contains evidence of proximity of land in the presence of fragments of plants and pulmoniferous mollusks, but the fossils throughout the carboniferous deposits of Nevada are of marine species, and no beds of coal occur in them. The whole series of formations of the upper Paleozoic presents strong contrast to anything seen in the eastern part of the continent, and the stratigraphy as well as the paleontology furnishes striking example of the unreasonableness of attempts to unify the geologic classifications of the world.

Mr. T. B. Comstock[3] in 1883 reported on the rocks of San Juan County, Colorado.

The Devonian rocks of this region are "exposed near the summit of the divide between Bear Creek and Cascade Creek and along a line running parallelwise with the Animas Cañon, forming the cliffs along the side of Lime Creek." The outcrop occurs again at Silverton and near the head of Cunningham Gulch. Although the Devonian is not sharply distinguished from the rocks below, the fossils in the upper part of the limestone point definitely to a Devonian horizon.

[1] Abstract of report, etc., p. 265.

[2] Walcott: Paleontology of the Eureka District, p. 4.

[3] Comstock, T. B.: Notes on the Geology and Mineralogy of San Juan County, Colorado. Trans. Amer. Inst. Min. Eng., vol. 17, 1883, pp. 165–191.

The Carboniferous rocks occur mainly in the southwestern part, along Lime and Cascade Creeks and branches of Mineral Creek. These belong to the Lower Carboniferous, and consist of argillaceous, arenaceous, and calcareous beds, having a thickness of some 1,200 feet, while those of the Upper Carboniferous are made up of red sandstones, 2,000 feet in thickness.

Mr. C. D. Walcott[1] reported identifications in the Grand Cañon as follows:

In the Grand Cañon of Colorado is found the Red Wall limestone of Gilbert forming the base of the Carboniferous series, and at the mouth of the Kanab Cañon about 1,000 feet of the Lower Aubrey sandstone are well exhibited. Evidences of Devonian rocks were noted resting upon the Tonto group (Cambrian), but in some places they were not recognized at all, and where they were seen they did not exceed 100 feet in thickness.

Mr. Frank Springer[2] reported that Burlington geologists, contrary to the ideas of others, have been inclined to divide the Burlington limestone into two parts upon paleontological evidence. This view is further demonstrated by finding a similar occurrence in Lake Valley mining district in New Mexico, thus showing its extended range.

Mr. A. C. Peale[3] in 1885 placed on record the first positive identification of Devonian strata in the Rocky Mountain region of Montana. Fossils were collected by the Hayden survey in 1872 from several localities in the Territory which Mr. Meek found to have a Devonian aspect, but he regarded them as belonging to the Lower Carboniferous, as they contained no strictly Devonian types of corals, crinoids, or lamellibranchs. The author visiting the region in 1884, in company with Dr. Hayden, obtained a collection of fossils which he submitted to Mr. Charles D. Walcott,[4] who identified them as undoubtedly Devonian.

Mr. Walcott says:

> Of the twenty-three species of fossils given in lists 1 and 2, twelve are identical with species occurring in the Upper Devonian of the Eureka district, Nevada. Of the others, two are Upper Devonian species in New York State, and *Athyris hirsuta* occurs at the base of the Carboniferous in the Eureka district.

The remaining forms resemble closely those of the Lower Carboniferous of the Eureka district.

Mr. A. McCharles[5] gave account in 1887, of the occurrence of Devo-

[1] Walcott, Charles D.: Pre-Carboniferous strata in the Grand Cañon of the Colorado, Arizona. Am Jour. Sci., 3d ser., vol. 26, 1883, pp. 437–442, 484.

[2] Springer, Frank: On the occurrence of the lower Burlington limestone in New Mexico. Am. Jour. Sci., 3d ser., vol. 27, 1884, pp. 97–103.

[3] Peale, A. C.: Devonian strata in Montana. Science, vol. 5, 1885, p. 249.

[4] Two lists of the fossils prepared by him are given, including in the first, *Discina lodensis* Hall (?), *Streptorhynchus chemungensis* Conrad, *Orthis Vanuxemi* (?) Hall (?), *Chonetes mucronata* Hall, *Productus speciosus*, *Spirifera disjuncta*, etc., and in the second are *Streptorhynchus chemungensis* Conrad, *Rhynchonella Horsfordii* Hall (?), etc.

[5] McCharles, A.: The footsteps of time in the Red River Valley, with special reference to the salt spring and flowing wells to be found in it. Manitoba Hist. and Sci. Soc., Trans., No. 27, 1887, p. 18. *Description of* occurrence of Archean, Ordovician, Silurian, Devonian, Cretaceous, and Quaternary.

nian and other Paleozoic formations in the valley of the Red River, British America. In the western part of the Red River Valley occurs a narrow belt of Devonian rocks, but their exact extent is not yet known. Devonian fossils belonging to the lower part of the system were found in river bowlders, probably transported from a distance by ice.

CHAPTER XI.

THE ACADIAN PROVINCE: THE CORRELATIONS AND CLASSIFICATIONS OF THE UPPER PALEOZOIC FORMATIONS IN THE ACADIAN PROVINCE.

The name "Acadian province" is applied geologically to the territory including the New England States, and the maritime provinces of Canada, i. e., Nova Scotia, New Brunswick, Cape Breton, and Prince Edward Island. Although at certain periods of geological time this region was little other than the northern extension of the great Appalachian province, it may be considered as distinct during the Devonian and Carboniferous ages. Its western limit may be arbitrarily fixed as the Green Mountains and the elevated hills just east of the Hudson River. The name is an adaptation of Sir William Dawson's term "Acadia."[1] The rocks under consideration find their typical representation in the region described in the "Acadian Geology."

The Carboniferous and Devonian systems are both represented in this region by extensive deposits. The author had devoted much time to a personal examination of the formations and had made a special study of the plant remains. The second edition presents some slight modification of the first in the classification. The classification is an expression of the general features of the Upper Paleozoic for this part of the continent at the time when it was written (1868). In chapter X and the following chapters, beginning at page 128, the classification and description of the Carboniferous system are given:

a. Upper coal formation, 3,000 + feet.
b. Middle coal formation, 4,000 feet.
c. Millstone grit series, 5,000 to 6,000 feet.
d. Lower Carboniferous marine formation or Carboniferous limestone, variable in thickness, characterized by marine invertebrates (*Productus cora*, *P. semireticulatus*, etc., with associated beds of gypsum and marls, and in some districts entirely represented by conglomerates.
e. Lower Coal Measures, holding some of the flora and fauna of the middle coal formation, but no productive coal beds; flora differing from that below in the Devonian, upon which it lies unconformably.

These last two divisions, "*e*" and "*d*," are considered as representing the Lower Carboniferous or "Subcarboniferous" of the western geologists.[2]

[1] Acadian geology: The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, by John William Dawson, etc. 1st edition 1856, 2d edition 1868.
[2] Page 131.

The top of this series is followed by the Triassic, resting uncomformably upon it.[1]

No Permian formations were known to the author, unless possibly the "upper coal formation may synchronize with the Permian of Europe" or "unless represented by the lower part of the sandstones of Prince Edward Island."[2]

Below the Carboniferous the following series of rocks of the Devonian system are reported from near St. John, New Brunswick:[3]

	Feet.
Mispeck group—Shales, sandstones, and conglomerates	1,850
Little River group—Upper part, conglomerates, sandstones, grits, and shales	2,350
Little River group—Middle and lower part, including the *Cordaite* shales in part and the *Dadaxylon* sandstone, shales, sandstones, and flags	2,800
Bloomsbury group—Conglomerates, tuffaceous rocks, and sandstones and shales	2,500

The upper part of the Devonian, correlated with the Chemung and Portage of New York, is reported in the "Gaspé sandstones" of eastern Canada. The typical section of the Carboniferous for this province is the famous South Joggins section along the coast of western Cumberland. It was measured and tabulated by Sir W. E. Logan in 1845; was examined and further reported by Lyell and Dawson in 1852 and 1853. Mr. Logan estimated the total thickness at 14,570 feet 11 inches. Mr. Dawson quotes it (pp. 156, et seq.) in detail. An abstract of the section is as follows:

		Feet.
Division 1.	Upper coal formation	1,617
2.	Upper coal, lower part	650
3.	Middle coal formation, upper part, including 23 coal groups	2,134
4.	Middle coal, lower part, with 49 coal groups	2,539
5.	Upper Millstone grit series	2,082
6.	Middle Millstone grit series	3,240
7.	Lower Millstone grit series	650
8.	Upper part, Lower Carboniferous formation	1,658

Immediately under these are beds of the marine limestone, containing *Productus cora*, etc. This correlation of the section is Mr. Dawson's. In an article read before the Philosophical Society in Philadelphia Mr. J. P. Lesley, having examined the coal field of Glace Bay, objected to the great thickness and to the correlation of the lower measures claimed by Mr. Dawson.[4] Mr. Lesley, chiefly upon lithologic grounds, urged that division 5 of the Joggins section is to be compared with the Lower Carboniferous on Vespertine No. XI of Pennsylvania, and that the deposits below (6, 7 and 8) would be Devonian. Mr. Dawson replied, and the substance of the debate is quoted in this volume,[5] claiming paleontologic evidence for his interpretation and, further, that the plants of the "Chemung of New York, of the Vergent and Ponent of Pennsylvania are decidedly Devonian."

[1] Acadian Geology, 2d ed., p. 128.
[2] Ibid., pp. 19, 126.
[3] Ibid., pp. 503, 504.
[4] Proc. Am. Phil. Soc., Phila., 1862.
[5] *Acadian* Geology, 2d edition, pp. 142–149.

The correlations of the Carboniferous and Devonian deposits of this Acadian province are based so greatly upon the evidence of plants that I will not here attempt to discuss the merits of the arguments, as the whole subject of the value of fossil plants as means of correlation is being considered by an expert paleobotanist. There are sufficient evidences of marine fossils to make clear that the base of the great series of arenaceous deposits overlying the Silurian in the Northeast is of Lower Devonian age and that the massive beds of limestone underlying the Coal Measures are Lower Carboniferous in age. The details are chiefly matters of classification within the Acadian province, and in any correlations that are made the fossil plant remains must be the chief witnesses.

As in the development of the geology of the Mississippian province, so in the development of that in the Acadian province, the coal beds were the guides to the general correlation, and the details were elaborated by degrees as the formations were studied.

In the following pages I have arranged in chronologic order brief abstracts of the results as they have been published, beginning with the year 1843, the few papers bearing upon this particular province prior to that date having been reviewed in the pages of the first chapter of this essay.[1]

In the year 1843 there appeared in the Quarterly Journal of the Geological Society, vol. 1, two articles on the geology of Nova Scotia and neighborhood, the first by Richard Brown.[2] In this paper the following formations were recognized: Coal Measures, Millstone grit, Mountain limestone, and the "Gypseous series." The latter were identified as occurring below the Carboniferous or Coal Measures. The second article is by J. W. Dawson,[3] and it has maps and sections and a description of the geological characters of the rocks. The Gypseous formation is referred to the Lower Carboniferous. Above them the author reported newer coal formations, and in the Red sandstone of Truro he reported another terrane, which was considered as "newer than any part of the coal formation."

In 1844 Lyell[4] in a short paper announced his opinion that these beds belong to the Carboniferous system.

In 1845 Dawson communicated a paper[5] to the Geological Society of London regarding the geology of Nova Scotia. In this paper the Carboniferous and Devonian formations are defined.

On East River, Pictou, occurs a series of Carboniferous rocks having

[1] In the preparation of these abstracts I have been assisted by Mr. V. F. Marsters, a graduate of Acadia College and now instructor in geology at Cornell University, whose assistance is hereby acknowledged.

[2] The Geology of Cape Breton, pp. 23-26 and 207-213, accompanied by a map.

[3] The Lower Carboniferous Rocks or Gypseous Formation of Nova Scotia, pp. 26-35.

[4] On the probable age and origin of a bed of plumbago and anthracite occurring in mica-schists near Worcester, Massachusetts. Am. Jour. Sci., vol. 47, pp. 214, 215.

[5] On the newer coal formations of the eastern part of Nova Scotia. By Dr. J. W. Dawson. Quar. *Jour. Geol. Soc.*, vol. 1, pp. 322-330.

a thickness of some 5,000 feet and forming the "older coal formation." Above it is a coarse Conglomerate, which is in turn followed by the "newer coal formation." This Conglomerate occurs at New Glasgow, where it dips to the north on West River, and at Mengonish Harbor. Above the Conglomerate occurs a gray fossiliferous limestone, followed by a small bed of coal, whose outcrop can be traced parallel with that of the Conglomerate at Mengonish, having a dip of 25°. Red sandstones are prominent in the lower part and gray sandstones in the upper part of this series. Fossilized wood is abundant, consisting chiefly of *Calamites* and *Lepidodendra*. In Rogers's Hill occurs a Conglomerate apparently identical with the New Glasgow deposit. This is followed by reddish sandstones and shales.

The author gives a coast section of the newer coal formation from Cape John, consisting of reddish sandstones and shale with gray beds and limestones containing ferns, etc., and associated with conglomerates and gypsum. A section is given of French River at Tatmagouche (6½ miles), showing the relation of the newer coal formation to rocks bearing scales of *Holoptychius*, probably of Devonian age. This series is seamed by Trappean rocks.

The newer series of the coal formation was formerly considered as part of the "New Red sandstone," and as including also part of the gypsiferous deposits and the nonfossiliferous red sandstone on the shores of the Bay of Fundy.

The author also adds a section showing the contact of the Carboniferous rocks with the Silurian rocks at Maccara's Brook. Their separation is well shown by the unconformable superposition of the Carboniferous series. This section is also considerably disturbed by intrusive rocks.

In the American Journal of Science[1] Charles Lyell gave an account of "The Coal Formation of Nova Scotia, etc." In regard to its position, he considered it the equivalent of the Carboniferous, but as lying below the productive Coal Measures. The general rocks consist of red sandstone, red marl, with subordinate beds of gypsum and marine limestone, and occasionally coal grits and shales with thin seams of coal.

Mr. Lyell[2] in 1845 discussed the Devonian and Carboniferous systems.

The Hamilton group (7), which the author considered as concluding the Silurian series of North America, ranges chiefly along the eastern and southeastern flanks of the Alleghanies, while the Devonian and Carboniferous series appear farther west. The Devonian rocks of North America the author considered as the equivalent of the Old Red sandstone series of North Britain and Herefordshire.

The coal fields of the United States, consisting of the Appalachian,

[1] Vol. 45, pp. 356–359.

[2] See also Travels in North America in the Years 1841–'42; with Geological Observations on the United States, Canada, and Nova Scotia, in which he defends his determination of the age of the gypsiferous strata as the "Lower Carboniferous." By Charles Lyell. Vol. 2, chap. 25.

the Illinois, and the Michigan fields, the fields in Canada, in New Brunswick, Prince Edward Island, Nova Scotia, and Cape Breton, are of great importance.

The Carboniferous series of Nova Scotia are conveniently divided into three parts: "(1) An upper series, composed of shales and sandstones bearing fossil plants; (2) a middle series, containing the productive Coal Measures; (3) the lower series, consisting of red sandstones and marls, with gypsum and limestones."

The Albion mines, near Pictou, show the greatest thickness of coal (some thirteen yards or more). An admirable section of the whole series is also seen on the South Joggins River, containing numerous fossil plants.

Mr. Richard Brown[1] reported in 1846 the finding, in the Sydney coal field of Cape Breton, in a stratum of arenaceous shale, of erect fossil trees, showing attached rootlets. This stratum, which has a thickness of 5 feet, occurs *below* the main seam of coal. Vast quantities of *Sigillaria* stems, *Calamites*, and *Lepidodendra* were also recognized, as well as a great variety of ferns.

In 1847 the same author reported upon the gypsiferous strata of Cape Dauphin.

Mr. Lyell had shown that the gypsiferous deposits of Nova Scotia and Cape Breton are closely connected with the older Carboniferous series, and are representatives of the Carboniferous limestones of Europe. The author proves this statement by giving a section from Cape Dauphin,[2] in which the gypsiferous deposits are separated from the red granites only by a small deposit of conglomerate and limestones. In this series the Millstone grit is represented by 200 feet in the Sydney coal field, but in places it reaches 2,000 feet. The thickness of the gypsum beds can not be easily ascertained. Their minimum thickness seems to be about 8 feet. No organic remains were noticed in the gypsum.

In 1850 Richard Brown[3] described the section of the lower Coal Measures of the Sydney coal field.

The series is grouped under four divisions, viz:

4. The Productive Coal Measures.
3. A thick deposit of sandstone.
2. Limestone and shales, occasionally containing beds of gypsum.
1. A coarse conglomerate.

The first division, "probably representing the Old Red sandstone of Europe," outcrops "from beneath the Carboniferous limestone, west of Sydney Harbor." The second division, having a thickness of 820

[1] Brown, Richard: On a group of erect fossil trees in the Sydney coal field of Cape Breton. Quart. Jour. Geol. Soc., vol. 2, 1846, pp. 393-396.

[2] Brown, Richard: On the gypsiferous strata of Cape Dauphin, in the island of Cape Breton. Quart. Jour. Geol. Soc., vol. 3, 1847, pp. 257-260.

[3] Brown, Richard: Section of the lower Coal Measures of the Sydney coal field in the island of Cape Breton. Quart. Jour., Geol. Soc. vol. 6, 1850, pp. 115-133.

feet, consists chiefly of shales, sandstones, and limestones, and contains a few brachiopods, fish scales, and plant remains. The third division consists of sandstones, probably equivalent to the Millstone grit of England, and has a thickness of 1,800 feet. The fourth division, containing the Productive Coal Measures, shows on Boulardrie Island a thickness of 5,400 feet, but at other exposures only 1,000 or 2,000 feet. The coal measures begin at Stubbord's Point and end at Cranberry Head. The dip is 60° east, at an angle of 7°. The author adds a tabulated section of each stratum, giving thickness and physical character, after which several sections are appended, showing erect fossil trees from various parts of the section.

In 1852 J. W. Dawson[1] gave an account of his studies of the red sandstones of Nova Scotia.

The author, by further examination, has been enabled to trace the "New Red sandstone" from the mouth of the Shubenacadie River by broken patches nearly to the mouth of the Avon, and at some points it was found in very close contact with Lower Carboniferous rocks. A continuation of the sandstone is seen in the Cornwallis Valley, as at Petite River, of which he gives a cut, showing the black slate, shales, and limestones lying immediately below the red sandstone, and dipping at a high angle. A similar exposure of red sandstone is also seen at Salter's Head, near the mouth of the Shubenacadie River. The shales referred to above are identical with those of Horton Bluff and Noel, both exposures containing *Lepidodendra*.

The New Red sandstones of Shubenacadie River rest unconformably upon shales of Carboniferous age.

In 1853 J. W. Dawson[2] gave an account of the Albert mine, Hillsborough. The author regards these deposits as belonging to "the lower part of the Lower Carboniferous series," and nearly equivalent to "a band of pseudo-Coal Measures occurring in the Carboniferous limestones of Nova Scotia."

A section from the Joggins Coal Measures to the Albert mine is given, in which the rocks consist of gray sandstones, reddish sandstones, limestones, and gypsums, conglomerates, and the calcareo-bituminous shales of the Albert mine. No shales resembling those of the Albert series have yet been recognized in the higher members of the Carboniferous system. Fish remains are abundant in the Albert shales. The plant remains, though rare, bear very close resemblance to those of Horton's Bluff.

The shales in contact with the coal are much contorted and folded. No *Stigmaria* were seen. Underclays were noticed as associated with the coal. The coal bed has a general dip of N. 15° E. The peculiar position of this deposit is explained by faulting. Concerning its origin,

[1] Dawson, J. W.: Additional notes on the red sandstones of Nova Scotia. Quart. Jour. Geol. Soc., vol. 8, 1852, pp. 398-400.

[2] Dawson, J. W.: On the Albert mine, Hillsborough, New Brunswick. Quart. Jour. Geol. Soc., vol. 9, 1853, pp. 107-114.

it may have originated, first, "from a hardening of bitumen," or, second, by the "bituminization of woody matter under continued pressure."

In 1853 Dr. Dawson[1] reported upon the South Joggins as follows:

In this region is represented a series of rocks, 14,000 feet in thickness, extending from the "massive limestone of the Lower Carboniferous series to the top of the Carboniferous formation."

The author gave a detailed account under twenty-nine divisions of a section in the middle of the formations, some 2,800 feet in thickness. The rocks consist of shales and clays containing plant remains, black carbonaceous shales intercalated by thin beds of coals, and sandstones showing ripple-marks and erosive effects previous to the deposition of the superimposed strata. Trunks of trees in situ, covered with *Spirorbis*, were found embedded in these sandstone strata, which contained *Calamites* and *Sigillaria*. *Stigmaria*, *Cypris*, and *Modiola* were quite numerous in the underclays. Some new facts are noticed showing the relation of *Stigmaria* and *Sigillaria*, and attention is called to the occurrence of *Coniferous* trees, *Calamites*, and *Poacites*, together with animal remains, consisting of scales, teeth, jaws, spines, and coprolites. An abstract is added of Mr. Logan's section of South Joggins Coal Measures. (See p. 239–241.)

Messrs. Poole[2] (Henry) and Dawson (J. W.) in 1854 compared the Albion Coal Measures with the section at the Joggins.

The thickness of the Albion Measures varies. While, according to Mr. Logan, the Joggins section showed seventy-six coal seams aggregating 44 feet, and Mr. Brown's section at Sydney, thirty-one seams showing 37 feet, at Pictou there are only two seams 60 feet in thickness. At the Albion mines the argillaceous beds are very thick, while the sandstones and shales seen at the Joggins and Sydney are absent. The coal beds with their associated rocks seem to be unconformable with the coal formation immediately below. This is explained by unequal deposition.

In the Albion mines occurs a thick, reddish conglomerate above the Coal Measures, which has no equivalent in the other mines of Nova Scotia. Its outcrop extends across the valleys of East, Middle, and West Rivers, Pictou, and dips toward the north. This is considered as the base of the "Newer Coal Formation."

A detailed account of the great bed is added.

In 1856 Mr. Dawson[3] gave his views regarding the classification of the rocks of Nova Scotia in a paper before the American Association.

Nova Scotia is occupied by rocks of the Silurian, Devonian, and Carboniferous series, and sandstones superseded by traps. The Carbon-

[1] Dawson, J. W.: On the Coal Measures of the South Joggins, Nova Scotia. Quart. Jour. Geol. Soc., vol. 10, 1854, pp. 1–12.

[2] Poole, Henry, and Dawson, J. W.: On the structure of the Albion Coal Measures. Quart. Jour. Geol. Soc., vol. 10, 1854, pp. 42–51.

[3] Dawson, J. W.: On the parallelism of the rock formations of Nova Scotia with those of other parts of America. Am. Assoc. Proc., vol. 10, Pt. 2, 1856, pp. 18–25.

iferous rocks are especially well developed and lie unconformably upon the Devonian rocks. The author proposes to outline the equivalency of these Canadian geological changes and formations with those of the American Paleozoic and Mesozoic in the United States.

After enumerating instances of *modern changes of level* evidenced by submerged trees and stumps in situ, found along the Bay of Fundy and near Fort Lawrence, and probably connected with those in progress in Newfoundland, Prince Edward Island, and the coast of New England, together with an outline of the distribution of bowlders and direction of transportation, he described the New Red sandstone immediately underlying the above series, which are well developed in Nova Scotia and Prince Edward Island, the latter not associated with traps.

The Carboniferous series was described in descending order under five stratigraphic divisions.

(1) "Upper or New Coal Formations," consisting of several thousand feet of sandstones, shales, gray beds with fossil plants, but without workable coal or massive limestones.

(2) The "Productive Coal Measures," presenting three different types of structure; (*a*) a large number of alternating beds of coal and stigmaria under clays; (*b*) the coal accumulated in a few large seams, but destitute of marine limestone and with erect trees; (*c*) presenting the aspect of the first series, but without coal and its accompaniments.

(3) A very thick series of "gray and red sandstones," barren of coal plants, corresponding in part to the "Millstone grits" of England and the "Conglomerates" of the Appalachian and Western coal fields.

(4) The "gypsiferous series," consisting of red sandstones, red and green marls, limestones with fossils, and beds of gypsum; this series is wanting in the Appalachian, but is well developed in the West and South. It was noted that when the Carboniferous beds of limestone approached the older ridges of rocks the limestones diminished and were replaced by conglomerates marking ancient sea beaches, while the deposition of limestone took place in deeper waters, thus presenting an analogy to similar facts observed in the United States.

(5) At the base of the system occur "estuary deposits" of dark calcareous shales and sandstones, with coal plants and fish scales, to which series the author refers the fish-bearing shales of the Albert mine in New Brunswick.

He noted the great similarity of the coal flora of Nova Scotia to that of the Southern and Western States and of England, while the marine fauna seemed to be more closly allied to that of western Europe.

The features of the Devonian and Silurian rocks were outlined. Before the dawn of the Lower Carboniferous period violent disturbances had occurred, elevating and fracturing the rocks. The first fossiliferous beds of great thickness were supposed by Prof. Hall to belong to the Clinton and Oriskany sandstone of New York. In some parts the organic life is remarkably like that of the English Upper Ludlow. These

beds, occurring about the horizon of the Niagara group, are interstratified with beds of greenstones, the whole series being cut by dikes, similar to regions of the same age in New England. The older Silurian rocks consist of nonfossiliferous rocks made up of quartzites and clay slates of great thickness, passing in places into mica, chert, and gneiss, destitute of calcareous, magnesian, and metallic minerals, with the exception of iron pyrites, but including no representative of the Silurian limestones of the United States and Canada, though occurring but a short distance from the Province of New Brunswick.

Isaac Lea,[1] in 1859, compared the "Trias" formations of the eastern border of the United States with the older rocks of Prince Edward Island.

Mr. Dawson, in referring to the older rocks of Prince Edward Island, had said that they "either belong to the top of the Carboniferous system or to an overlying deposit of the Permian or Triassic age." Mr. Lea remarked that the rock in the bed of Deep River, North Carolina, formerly considered by Prof. Emmons as Trias, was in 1856 by him divided into two groups, Permian and Trias. He considered that the Chatham series of North Carolina, the Newark series of New Jersey, and the Greenfield series of the Connecticut Valley represent one epoch, the Permian. The Groynedd series and that of Phœnixville are evidently of the same horizon with the above mentioned. Prof. Emmons agrees with Mr. Lea in referring these rocks to the Permian epoch, identified as they are in North Carolina by the same Saurian forms, plants, fish scales, and the *Posidonia*.

Charles H. Hitchcock,[2] in 1860, made the following correlations of the coal beds of New England:

By means of the fossil plants Mr. Lesquereux had been able to systematize the Carboniferous coals. From comparison of his identifications Mr. Hitchcock concluded that the New England coal basins of Wrentham, Valley Falls, Portsmouth, and Newport, Rhode Island, belong to the lower series, probably below the Mahoning sandstone, and if the upper Coal Measures of other basins were ever deposited there they have been obliterated by denudation.

In a letter to Mr. B. Silliman, jr., Mr. O. C. Marsh[3] corrected a mistaken report that the Saurian vertebræ from Nova Scotia (discovered by Marsh in 1855) had been recently found by Agassiz. Mr. Marsh had postponed announcing the discovery, hoping to obtain further remains, but failing to do so, makes it public in this letter, saying that he found the bones beneath 5,000 feet of coal strata; that they resemble the vertebræ of an Ichthyosaurus; and he proposes for the species the name *Eosaurus Acadianus*.

In 1863, in the "Geology of Canada," the Devonian system was recog-

[1] Lea, Isaac: On Age of Trias of Eastern United States. Phila. Acad. Sci., Proc., vol. 10, 1859, pp. 90-92.

[2] Hitchcock, C. H.: Synchronism of Coal Beds in the New England and Western United States Coal Basins. Am. Assoc., Proc., vol. 14, 1860, pp. 138-143.

[3] *Marsh, O. C.*: On the Saurian Vertebræ from Nova Scotia. Am. Jour. Sci., vol. 33, 1862, p. 278.

nized by Logan in Canada West. Acknowledgments were made of the services of James Hall in tracing out in 1856 with Mr. Murray the boundary of the Upper Devonian rocks in a part of the western peninsula.

In the report[1] Logan recognized the Oriskany, Corniferous, Hamilton, Portage, and Chemung formations of the New York system. Reference is also made to the correlation of the higher Carboniferous rocks in Michigan and their relation to these Devonian rocks.

The Oriskany sandstone is reported from Waterloo, on the Niagara River, and extending westward at Oneida and North Cayuga, but is not recognized beyond the township of Windham. It is from 6 inches to 25 feet thick, but is frequently missing between the Waterlime and Corniferous formations.

The Corniferous formation is estimated at 160 feet. It presents various characters, cherty limestone, calcareous shales, light or dark, bituminous and hydraulic beds being reported at different localities.

A series of shales and shaly limestones is reported as "Hamilton formation." At Bosanquet the following section is seen:

	Feet.
Gray Encrinal limestone	2
Soft shales	80
Solid Encrinal limestone	2
Gray calcareous shales (*Spirifer mucronatus*)	4
Gray calcareous beds	25

At Austin Mill, 50 or 60 feet below the Encrinal limestone, occurs a solid arenaceous limestone, 7 inches thick, under which are black shales doubtfully referred to the Marcellus shales. The soft marly beds, with thin beds of limestone intercalated, containing *Spirifer mucronatus*, are also referred to the Hamilton formation. The thickness of the formation is estimated at 300 feet. In several localities (Cape Ipperwash, Kettlepoint, Bosanquet) a black, fissile, bituminous shale, 12 to 14 feet thick, weathering gray and holding spheroidal concretions, is correlated with the Genesee shale. The author expresses the opinion that the 363 feet of rocks in Michigan called "Chemung" and "Portage" by Winchell lie above the "Black shale."

In a paper[2] describing his studies of the Coal Measures on the coast of Cape Breton, J. P. Lesley[3] called in question the reported thickness of the Coal Measures. He said: "The geologists, Sir William Logan, Sir Charles Lyell, Professor Dawson[4] and other geologists who have described the Coal Measures of Nova Scotia and New Brunswick agree in assigning to them an almost incredible thickness."

---

[1] Geological Survey of Canada: Report of progress from its commencement to 1863; illustrated by 498 wood cuts in the text. Montreal, 1863, 8vo., xxvii and 983 pp., by W. E. Logan.

[2] This discussion is referred to at the opening of the present chapter. The original papers were published in the American Philosophical Society Proceedings.

[3] Lesley, J. P.: Section of Coal Measures on the Cape Breton coast. Am. Phil. Soc. Proc., vol. 9, 1863, pp. 93–109, 167–170; Am. Jour. Sci., 2d ser., vol. 36, pp. 179–196 (Revised).

[4] Dawson, J. W.: Note on Lesley's paper on the Coal Measures of Cape Breton. Am. Phil. Soc. Proc., vol. 9, 1863, pp. 163–167, 208, 209.

The section of which Mr. Lesley gave a full account is situated between Luigan and Great Glace Bays on the east coast of Cape Breton. It includes the "Productive Coal Measures" of Cape Breton with five workable beds. In the North Sydney measures Mr. Brown has recorded thirty-four seams, but only four of them are workable, varying from 3 to 7 feet in thickness.

The author concluded that Mr. Brown's estimate of 10,000 feet for the Productive Coal Measures is too great. He added an analysis of Logan's "Joggin's section" having "a vertical thickness of 14,570 feet," and containing "seventy-six beds of coal, and ninety distinct Stigmaria underclays," and "twenty-four bituminous limestones."

In Dr. Dawson's reply he took exception to Mr. Lesley's views under the following heads: (1) It is not safe to make comparisons between the greatly developed Coal Measures of Nova Scotia and the thinner beds of the west; (2) The Coal Measures were deposited on the sides of the Silurian and Devonian hills in separate areas and not over the hilltops; (3) It is useless to make comparison between even the Joggins section and those of Wallace and Pictou. "A fortiori, detailed comparison with Pennsylvania and more distant localities must fail;" (4) "The whole of the Coal Measures in the Joggins section belong to the Upper and Middle Coal Measures. It is quite incorrect to indentify No. 6 of Logan's section with the Lower Coal Measures;" (5) "The flora is identical throughout the whole thickness of the Middle Coal Measures;" (6) The flora of the gypsiferous deposits and marine deposits of Nova Scotia is certainly Carboniferous, while the flora of the so-called "Chemung" is as decidedly Devonian.

In a letter[1] to the editors of the American Journal of Science, Dawson combats the action of some geologists in referring certain rocks, hitherto regarded as Upper Devonian, to the Carboniferous period, and gives facts derived from his own study of fossil plants which, he thinks, bear strongly against this view. Of all the species of Devonian land plants that have come under his observation, both of America and Europe, only an exceedingly small number are Carboniferous. In the Carboniferous system, in spite of numerous differences between the plants of the lower, middle, and upper divisions, "there is a grand unity of the fossil flora throughout." But when the Devonian is reached, there are new genera and a distinct assemblage of species. The author speaks of but one exceptional case, which is that of beds at Akron and Richfield, Ohio, regarded as equivalent to the Upper Devonian of New York. In a small collection from these places he saw two species which were identical with Lower Carboniferous forms, while the others, though having a Devonian aspect, were not identical with any New York or Gaspé species.

While it may be, he says, that in the Paleozoic period the range in time of marine forms exceeded that of terrestrial life, it would be an

[1] *Dawson, J. W.*: On American Devonian. Am. Jour. Sci., vol. 35, 2d ser., 1863, pp. 309-311.

anomaly to have a stratum of rocks include one flora and a part of another almost entirely distinct and characteristic of another period. But he thinks the gap greater in Eastern America between the Devonian and Carboniferous periods than it is elsewhere. The Ohio plants mentioned indicate passage beds, but in that case the author would suppose them to be newer than the Chemung group, and wanting or represented by barren deposits in New York.

In another paper,[1] which is copied into the American Journal of Science, from the Quarterly Journal of the Geological Society (with the exception of Part II, containing descriptions of species, which is omitted), Dr. Dawson speaks of the large number of species of the Devonian flora, more than 60, which he has had the opportunity of examining, from the collections of Messrs. Matthew and Hartt, Professor Hall, and Professor Hitchcock, and notices the geological character of the localities in which they are found, with lists of the fossils found in each. The localities are in the States of New York and Maine, in Canada and New Brunswick. The rocks of St. John in New Brunswick, from which a copious flora has been obtained, are described in detail, and a summary given of the deposits.

At the close conclusions are drawn from the observations recorded in the preceding part of the article as follows: (1) That the Devonian flora resembles the Carboniferous in its general character in the prevalence of Gymnosperms and Cryptogams, and the generic types of the two periods are nearly the same. Of thirty-two genera described, only six are peculiar to the Devonian period, though some are much better represented in the Devonian than in the Carboniferous, and several Carboniferous genera are wanting in the Devonian. (2) A majority of the species of the Devonian do not reappear in the Carboniferous, but a few species extend from the Upper Devonian into the Carboniferous, establishing a passage from the earlier to the later flora. But this connection is less close than that between the Lower Carboniferous and the true Coal Measures. (3) A large part of the difference between the two floras is owing to the different geographical conditions. (4) The conditions were less favorable to the preservation of plants in the Devonian than in the Carboniferous period. (5) The Devonian flora was not of lower grade than that of the coal period, but we find in it more points of resemblance to the floras of the Mesozoic period and of modern tropical and austral islands than in that of the true coal formation. (6) The *facies* of the Devonian flora in America is very similar to that of the same period in Europe, but the number of identical species in the coal fields of the two continents is greater. These conclusions do not differ materially from those of Goeppert, Unger, and Bronn, after consideration of the Devonian flora of Europe.

In a letter from Leo Lesquereux[2] the following points regarding cor-

[1] Dawson, J. W.: On the Flora of the Devonian period in Northeastern America. Am. Jour. Sci., vols. 35, 36, 1863, pp. 311–319, 41, 42.

[2] Lesquereux, Leo: On the character of the Millstone grit or Subcarboniferous conglomerate in the far West. Am. Phil. Soc., *Proc.*, *vol. 8, 1863*, pp. 198–204.

relations of Nova Scotia formations are recorded, reviewing the paper above mentioned:

The first section described is situated 14 miles southwest of Fayetteville, in Washington County, Arkansas, and the second was made from the base to the top of the Boston Mountain, in Johnson County. The Millstone Grit Measures seem more persistent and greater in thickness in Arkansas than in the East, and may be greater than has been made out at Horsehead Mountain. From an examination of these sections, the author thinks that the "Nova Scotia basin is a separate member of our great American coal field," and agrees with Dawson that the flora of both countries is apparently the same. But while Dawson finds abundance of coniferous trees, and English geologists find them abundant in the Coal Measures of England, the author claims, in comparing sections of the East and West, that he finds none in his western section. The increased thickness of the sandstones and shales of the eastern deposits, in comparison with those of the West, and the local variations, the author accounts for by the fact that they are *shore* formations, and hence Dawson's sixth objection is not applicable to western deposits. The author in conclusion shows from Dawson's own statements that there is a gradual change throughout the flora of the Coal Measures, and even from Devonian to typical Carboniferous plants, while Dawson would claim there was a much less intimate connection between Upper Devonian and Lower Carboniferous than is apparent throughout the whole Carboniferous system.

G. F. Matthew[1] in 1865 commented on the "Fern ledges" of Lancaster, New Brunswick, in the following way:

The Middle and Upper Devonian rocks are known under three groups: The "Bloomsbury group," No. 4 of Dawson's list; "Little River group," Nos. 2 and 3, Dawson's list; "Mispeck group," No. 1, Dawson's list. These groups, lying unconformably on the Silurian, and in some places upon the Laurentian rocks, occupy a great part of the district towards the head of the Bay of Fundy. They contain numerous plant beds, and seem to be connected with those of Perry, Me. St. John County is largely covered by Devonian rocks, and detached pieces occur throughout Charlotte County. Dawson says that "the plant remains combine the features of the Hamilton and Portage groups." Professor Hitchcock also reports Devonian areas in northern Maine. The thickness of the Devonian sediments below the plant beds is about 5,000 feet.

The Lower Carboniferous rocks extend over Kings, Albert, and Westmoreland Counties, being about 100 miles in length, with varying width. They also occur along the Kennebeccasis Bay and in detached areas along the Bay of Fundy. They consist mainly of limestones, shales, and sandstones, associated with pyroschists resembling those

[1] Matthew, George F.: On the Devonian plant locality of the "Fern ledges," Lancaster, New Brunswick, with a detailed section and notes on the fossils.

Observations on the Geology of southern New Brunswick, by L. W. Bailey [et al.], pp. 131–140. Fredericton, 1865.

of the Albert mine, and yielding *Lepidodendrons*, *Cyclopteris*, and other Carboniferous forms. The Carboniferous rocks, consisting of gray sandstones and shales, cover the central and eastern part of New Brunswick. There is a slight nonconformity between the Lower Carboniferous and the Coal Measures of about 15°. They also appear in Westmoreland County, and extend along the north shore of the Bay of Fundy.

Dawson[1] in 1866 gave an interesting discussion of the conditions of deposition of coal, in which the classification and thickness of the Acadian formations are stated.

According to the estimates of Logan the Coal Measures at the Joggins are 14,570 feet in thickness, the deposits of Pictou 16,000 feet, and those of Cape Breton, according to Mr. Brown, 11,000 feet, excluding the Lower Carboniferous deposits.

The author arranged the Carboniferous series in the following groups:

(*a*) Upper coal formation, consisting of sandstones, shales, conglomerates, and thin limestones, bearing numerous plant remains.

(*b*) The middle coal formation, or Coal Measures proper, containing all the coal beds, but no limestones. Plant remains are quite abundant.

(*c*) The "Millstone grit," including the sandstones and shales, lying just below the Coal Measures. It contains the trunks of coniferous trees.

(*d*) The Lower Carboniferous marine formation.

(*e*) The Lower Carboniferous Coal Measures, or Lower Coal Measures. "The last two groups are equivalent to the 'Subcarboniferous' of American geologists." But the author did not find in Nova Scotia any reason for applying any more explicit term than "Lower Carboniferous."

There seem to have been three distinct conditions of deposition during the middle coal formation: (1) Deposition of coarse sediments, alternating with clays, sands, and gravels; (2) precipitation of limestone and growth of corals and shellfish; (3) deposition of fine sediments and accumulation of vegetable matter between bituminous limestones and shales.

The condition of the Devonian rocks shows that there was considerable igneous action at the close of the Devonian period, and before the deposition of Carboniferous rocks, from the fact that they are partially metamorphosed by the effects of injection of igneous matter.

The author thinks that the time of greatest depression was during the deposition of limestones; the time of greatest elevation took place during the formation of the coal beds, and the condition for the formation of the "Millstone grit" was intermediate. These remarks apply to New Brunswick as well as to Nova Scotia. The local differences are of the same character as those of the Appalachian and western fields and those of Great Britain.

There is marked evidence of a disturbance during the Carboniferous period, producing synclinal and anticlinal folds, similar to those of the

[1] Dawson, J. W.: On the conditions of the deposition of coal, more especially as illustrated by the coal formation of Nova Scotia and New Brunswick. Quart. Jour. Geol. Soc., vol. 22, 1866, pp. 95–166, plate.

Devonian period, and hence causing irregular deposition and local denudation, a condition very common in Nova Scotia.

The author has been unable to account for the separation between the lower and middle coal formations, but thinks "it may include much of the 'Lower Coal Measures' of Rogers in the Pennsylvania coal field." He maintains that the order of sequence noted in the Carboniferous period has its parallel in each of the other periods of the Paleozoic age, "each of which was characterized by a great subsidence and partial reelevation, succeeded by a second very gradual subsidence."

A detail account was given of the stratification of the South Joggins section and discussed under three divisions:

(1) Logan's section, 1,617 feet in vertical thickness on the shore of Shoulie River.

(2) Ragged Reef and vicinity, 650 feet in thickness, forming the lower part of the upper coal formation.

(3) From Ragged Reef to McCavins Brook, 2,134 feet in thickness, including 1,009 feet of sandstone, 912 feet of shales and clays, and 22 coal beds. This is probably equivalent to the "Upper Coal Measures" of American geologists and includes also the "Middle Coal formation."

In 1867[1] the same author announced some recent discoveries in the Acadian provinces of British America. He said the discovery of a land flora in a series of rocks near St. John, New Brunswick, underlying unconformably the Lower Carboniferous, has proved the presence of rocks of the Devonian age. For this discovery we are indebted to Messrs. Matthew, Hartt, and Bailey. With the flora were found six species of insects which have been described by Mr. Scudder. They are the first insects found below the Carboniferous. Below the Devonian shales and sandstones occurs a thick series of rocks embracing a fauna of Silurian aspect. This division is termed the "Acadian series." The labors of Mr. Davidson, Mr. Hartt, and the author have brought to light fossils closely allied to Permian species.

The announcement of the correlation of Devonian rocks in Maine was made by C. H. Hitchcock[2] in 1867.

A series of slaty deposits in Washington County, Maine, was referred to the "Lower Helderberg" and "Upper Devonian." In the northern part of the State occur the representatives of "(*Oriskany*) Cauda-galli grit" and other fossiliferous zones of Devonian strata.

A reconnaissance made for the government of New Brunswick[3] by Messrs. Matthew and Bailey, in connection with C. F. Hartt, brought to light a wide distribution of Devonian rocks along the shore of St. John River. After describing the occurrence of the lower metamorphic

[1] Dawson, J. W.: On recent geological discoveries in the Acadian provinces of British America. Am. Assoc. Proc., vol. 16, 1867, pp. 117–119.

[2] Hitchcock, Charles H.: Explanation of a geological map of Maine. In Am. Ass. Proc., vol. 16, 1867, pp. 123.

[3] Matthew, George F., and Bailey, L. W.: Remarks on the age and relations of the metamorphic rocks of New Brunswick and Maine. Am. Ass., Proc., vol. 18, 1869, pp. 179–195.

rocks, the authors gave a detailed account of the Siluro-Devonian formation occurring on each side of the granite ridges to the south of the Carboniferous. These sediments they divide into a lower and upper division, each of which is subdivided into two series. These occur chiefly in St. John, Charlotte, and Queen Counties. A gradual passage from the granites to undoubted Siluro-Devonian rocks is well exhibited in the Nerepis Valley and on the eastern shore of the St. Avise River, Charlotte County. A similar series occurs in Perry, Maine. The granitic rocks at the base are not considered as Siluro-Devonian.

The lower division consists of two series: First, limestones, felsites, etc.; second, gray sandstones, black slates, and *Dadoxylon* sandstones. These are followed by a series known as the "Mispec rock," consisting of diorites, conglomerates, and slates, which are followed by the green "Cordaite" slates.

The authors state that further investigations indicate that the Nerepis granites, formerly considered as Devonian, must be regarded as of Upper Silurian age, if not older.

Mr. Edward Hartley made a report[1] of a part of the Pictou coal field in the year 1870. The region reported upon lies "between the East and West Rivers of Pictou, and extends laterally from Conglomerate ridge, a prolongation of Fraser's Mountain, on the north of New Glasgow, to the Fox-brook Road, between the coal mines and Hopewell Village." The rocks are described under the following divisions:

1. Pre-Carboniferous.
2. Millstone grit.
3. New Glasgow Conglomerate.
4. Productive Coal Measures.

The rocks here called "pre-Carboniferous" were observed by Mr. Dawson, and in his "Acadian Geology" are said to be "probably of Devonian age." They consist of metamorphic rocks, mainly siliceous slates and conglomerates, and in one locality, Waters' Quarry, a limestone of 20 feet thickness. Comparing his section with the classification of the Carboniferous published in Dawson's Acadian Geology, viz, "(5) Lower Coal Measures, (4) Carboniferous limestone, (3) Millstone grit series, (2) Middle Coal formation, (1) Upper Coal formation," the author considered all but the (3) "Millstone grit series" and the (2) "Middle Coal formation" to be wanting; and in some places he found the Devonian rocks followed by the Middle Coal formation without even the Millsone grit.

The section at McLeod's Brook[2] represents 3,773 feet of sandstones and conglomerates; on East River, above Albion mine, 1,402 feet of sandstones; both of these are referred to the Millstone grit. Impure limestone beds are seen in the lower part of the formation in the East

[1] Hartley, Edward: Report on a part of the Pictou coal field. Geol. Survey Canada; Report of Progress for 1866–1869, 1870, pp. 55–107.

[2] Ibid., p. 60.

River section. On the west bank of East River, at New Glasgow bridge, occurs the New Glasgow conglomerate, 450 feet thick. The pebbles are of Millstone grit and Devonian, and in some cases the cementing matter is calcareous. A section of these conglomerates, at Alma Mills bridge, of 1,372 feet, is reported. This conglomerate, intermediate between the Millstone grit and the Productive Coal Measures, is the base of Dawson's Middle Coal formation. Tracing it westwardly it was found in places to lie directly upon altered Devonian rocks.

In describing the Productive Coal Measures the author gives a detailed account of the Measures at the Albion and Acadia mines, in which fourteen coal seams are mentioned, the total thickness of the Albion being 2,452 feet 11 inches. To show the variation in the character of the rocks in this section an account is given of the Forster Pit section. The Productive Measures are situated between three faults: one on the north passing through New Glasgow, one in the west bringing the Devonian series and Millstone grit in contact with the Coal Measures, and the third on the south side of the area. In this area are two synclinal folds running in an east and west direction, and designated as the Albion and Bear Creek synclinals; both are limited by the west fault.

Charles Robb, in 1870,[1] made a report on part of New Brunswick.

The Lower Carboniferous rocks of New Brunswick "lie between the southern boundary of the county of York and the unconformable altered slates to the northwest." They consist mainly of sedimentary deposits derived from the neighboring metamorphic hills. These deposits are occasionally invaded by igneous intrusions. The sandstones are of a reddish color, and at places contain considerable micaceous and calcareous matter. The author considers them to be about 1,000 feet in thickness. No fossils were observed.

The Upper Conglomerate consists of siliceous material, not calcareous, followed by gray sandstones containing *Calamites*, *Cordaites*, and other vegetable remains, with an occasional seam of coal.

The following classification of the Pictou coal field was made by Sir William E. Logan in 1870:[2]

Pre-carboniferous or Devonian....1. Conglomerates, quartzites, and compact slates.

Carboniferous
- 2. Greenish gray and red sandstones, with conglomerates and impure limestones.
- 3. Red coarse conglomerates.
- 4. Productive Coal Measures.

The rocks of the first series form parts of McGregor's and McLellan's Mountains. The author called them "pre-Carboniferous," and assigned them to the Devonian age on the authority of Mr. Dawson, who gave them that position in his "Acadian Geology." The author considered

[1] Robb, Charles: Report on the geology of a part of New Brunswick. Geol. Survey of Canada; Report of Progress for 1866–1869, pp. 173–209, map.

[2] *Logan, W. E.*: Report on a part of the Pictou coal field. Geol. Survey of Canada; Report of Progress for 1866–1869, 1870, pp. 3–17, map.

them as pre-Carboniferous, but found no direct evidence of their age. He identified them as occupying the same place in the series with similar rocks reported on the west side of East River by Mr. Hartley.

The second series, which he identified with the "Millstone grit" of Dawson's Acadian Geology, and with "Bonaventure formation" of Gaspé, and the "Millstone grit" of England, occurs on the east side of East River in a triangular area, and near the foot of Fraser's Mountain. Thin, impure limestones, carrying fossils, among them *Spirorbis carbonarius*, were noted at McLellan's Brook. For this formation he proposed the name "Grindstone grit."

The third series, named by Dawson the "New Glasgow Conglomerate," has a total thickness of 1,600 feet. It covers the south flank of Fraser's Mountain. In a white arenaceous limestone, 3 miles eastward of New Glasgow, occurring in the midst of a series of sandstones, shales, and other concretionary limestones, was discovered a number of minute coiled shells, referred to a new species of *Spirorbis*, and described by Dawson under the name of *Spirorbis arietina*.

The fourth series, the "Productive Coal Measures," is well represented by a section along McLellan's Brook, between McLellan's and McGregor's Mountains, but the upper part of the series is not shown in this section.

In 1871 Prof. Hitchcock[1] announced the discovery of Helderberg corals in Littleton, New Hampshire. The limestone containing the corals was traced for about 3 miles, and appeared to be duplicated by a synclinal fold. It overlies the metamorphic Quebec group on one side, and probably the Coös group on the other, and appears to be overlaid by a clay slate carrying a few worm trails. The corals were obscure, and were submitted to the examination of E. Billings, of Montreal. He recognized *Favosites basilica* and a *Zaphrentis*. The rock appeared to be identical with the Canadian limestone 55 miles to the northwest, supposed to range from the Lower to the Upper Helderberg.

Messrs. Bailey and Matthew, in 1872,[2] presented their preliminary report on the geology of southern New Brunswick. In this article the Devonian rocks of St. John County, New Brunswick, are described under the following classification:

Bloomsbury conglomerate.—Coarse reddish gray rock, red shales interstratified; thickness 500 feet.

Dadoxylon sandstone.—Sandstone and grits, with dark green shales; 2,800 feet; containing fossils, plants, crustacea, and wings of insects.

Cordaites shales and flags.—Two thousand four hundred feet, containing numerous plant remains.

Mispec conglomerate.—One thousand eight hundred feet.

The Devonian rocks of Lepreau Harbor are separated from those of

[1] Hitchcock, C. H.: Helderberg Corals in New Hampshire. Am. Jour. Sci., 3d series, vol. 2, 1871, pp. 148, 149.

[2] Bailey, L. W., and Matthew, G. F.: Preliminary report on the geology of southern New Brunswick. Geol. Survey Canada: Report of progress for 1870–'71, 1872, pp. 13–240.

St. John Harbor by a ridge of Laurentian gneiss. A similar division was also noted east of the same harbor. "The northern limit of Devonian rocks in the eastern part of St. John County may be traced from Carleton Heights across the harbor of St. John, through the southern part of the city of the same name." They occur again at Little River, and farther west at Black River, near Bloomsbury Mountain; thence south to Milligan's Lake, thence northeast toward Quaco Hills. In the western part of St. John County they overlie the Laurentian and Huronian series, but occupy only isolated patches, which, however, have been traced as far east as Charlotte County.

Reference was also made to the occurrence of sedimentary rocks "at Oak Bay and in the Nerepis Hills, which may correspond to the 'Dadoxylon sandstones' of St. John County." Also in northwest Charlotte occurs a series of argillites and sandstones resembling in appearance the "Cordaites group" of St. John County, but including a greater thickness of arenaceous beds.

The "Perry sandstone group," which is typically represented at Perry, Maine, is also seen at St. Andrews, New Brunswick. Although this sandstone contains plants of the Upper Devonian type, the author is inclined to consider it as lying at or near the base of the Lower Carboniferous, and characterized by an Upper Devonian flora. Similar conditions were also noted at Point Lepreau. The author gave a list of the fossil plants found in the Perry sandstone.

The "Lower Carboniferous rocks" of eastern and central New Brunswick occupy the Belleisle and Kennebeccasis Valleys, Kings County, extending along Petitcodiac River through Albert and Westmoreland Counties, around the margin of the central coal field, through Queen's, York, Northumberland, and Gloucester Counties to Bay Chaleur. Isolated areas also occur in Victoria and Carleton Counties. The "Carboniferous rocks" proper occupy by far the largest territory of any series in New Brunswick. They cover the counties York, Queen's, Sunbury, Kent, and Northumberland. Their most northerly limit is at Bathurst, Bay of Chaleur, the most southerly at Shediac, Westmoreland County. They consist mainly of sandstones, shales, and conglomerates of gray color and coarse texture. A list of the fossil plants of this series was also given.

Mr. L. W. Bailey,[1] in 1872, recorded the occurrence of undoubted Carboniferous rocks bearing plants in the eastern part of Kings County belonging to the Upper or Middle formation. There is also evidence of nonconformity between the Coal Measures and the Lower Carboniferous formation.

Mr. Charles Robb,[2] in 1872, reported that the Carboniferous rocks of northwestern New Brunswick consist mainly of arenaceous shales and

[1] Bailey, L. W.: Report on geological investigations in New Brunswick. Geol. Survey Canada: Report of progress for 1871–'72, 1872, pp. 142–144.

[2] *Robb, Charles*: Supplementary report on the geology of Northwestern New Brunswick. Geol. *Survey Canada*: Report of progress for 1870–'71, 1872, pp. 241–251.

gray, yellowish, and purple sandstone, 180 feet thick. They are locally calcareous and arenaceous. Southwest of Miramiche River the calcareous conglomerate is much disturbed by eruptive masses. Reference is also made to the Brighton outlier, which is situated between the north and south branches of Beccaguimac River, and contains Devonian plants. Although fossils of Devonian type have been found in this formation, in its physical characters it resembles the Lower Carboniferous rocks. Other small areas were noted to the northwest in Windsor Settlement.

Dr. Dawson reports the following correlation and classification for Canadian Carboniferous rocks in 1873:[1]

The Carboniferous rocks of Canada lie unconformably upon the Devonian and Upper Silurian formations. The author classifies them as follows:

(1) Horton Bluff series, or Lower Carboniferous Coal Measures, consisting of hard sandstones, calcareous shales, with conglomerate and grit, bituminous shales, and underclays, with plants and coal seams, with fishes and footprints of Batrachians.

(2) Windsor series, or Lower Carboniferous limestone and gypsiferous beds; marine and holding shells of the Lower Carboniferous period, containing limestones, marls, clays, and gypsum.

(3) Millstone grit series, consisting of conglomerate, shales, sandstone, and thin beds of coal, containing Naiadites. Thickness 5,000–6,000 feet.

(4) (*a*) Middle coal formation, and the (*b*) upper or newer coal formation.

The Lower Carboniferous deposits of Gaspé and Bay Chaleur, New Brunswick, consist mainly of sandstones and conglomerate, with few fossils, while in southern New Brunswick the bituminous shales attain a great thickness, as also does the Millstone grit. On Salmon River, West, East, and Middle Rivers of Pictou, the Millstone grit consists of chocolate sandstones and shales holding plants. Beneath the Millstone grit of Pictou, known as the "New Glasgow Conglomerate," occurs a hard sandstone holding fossils, which Mr. Dawson regarded as of Devonian age.

The author gave the following list of equivalents of the divisions proposed for the Canadian rocks, viz:

I.—*Equivalents of the Lower Carboniferous Coal Measures, or Horton series:*

(1) The "Vespertine group" of Rogers in Pennsylvania.
(2) The "Kinderhook group" of Worthen in Illinois.
(3) The "Marshall group" of Winchell in Michigan.
(4) The "Waverly sandstone" (in part) of Ohio.
(5) The "Lower or False Coal Measures" of Virginia.
(6) The "Calciferous sandstone" of McLaren, or "Tweedian group" of Tate in Scotland.
(7) The "Carboniferous slate" and "Coomhala grits" of Jukes in Ireland.
(8) The "Culm" and "Culm Grauwacke" of Germany.
(9) The "Grauwacke" or "Lower Coal Measures" of the Vosges, as described by Schimper.

[1] Dawson, J. W.: Introductory sketch of the geology of the Lower Carboniferous Coal Measures, and Millstone grit, with the equivalent formations abroad. Geol. Survey Canada: Report on Fossil Plants of the Lower Carboniferous and Millstone grit of Canada. Montreal, 1873. Pp. 5–14.

I.—*Equivalent of the Lower Carboniferous Coal Measures, or Horton series*—Continued.

(10) The "Older Coal formation" as described by Eichwald.

(11) The so-called "Ursa Stage" of Heer includes this, but he has united it with Devonian beds, so that the name can not be used except for the local development of these beds at Bear Island, Spitzbergen.

II.—*Equivalents of the Millstone grit are:*

(1) The "Seral Conglomerate" of Rogers in Pennsylvania, etc.

(2) The "Lower Coal formation," "Conglomerate," and "Chester" groups of Illinois (Worthen).

(3) The "Lower Carboniferous sandstone" of Kentucky, Alabama, and Virginia.

(4) The "Millstone grit and Yoredale rocks" of North England and the "Culmiferous rocks" of Devonshire.

(5) The "Moor Rock" and "Lower Coal Measures" of Scotland.

(6) "Flagstones and lower shales" of the south of Ireland and "Millstone grit" of the north of Ireland.

(7) The "Jungste Grauwacke" of the Hartz, Saxony, and Silesia.

The author also gave a short account of the distribution of the Carboniferous rocks in Nova Scotia and New Brunswick. The equivalent of the "Millstone grit" of Logan's section at "the Joggins" has a thickness of 5,972 feet. This series is also found on the flanks of the Cobequick Mountains, and running eastward connects with the Pictou coal fields. Another noted area lies south of Mira's Basin, which is called the "Horton Bluff series," and similar outcrops were noted at Walton, Noel, Windsor, and Shubenacadie.

The "Millstone grit series" is also well developed on Salmon River, West, East, and Middle Rivers, Pictou. Beneath it, in Pictou County, occur hard sandstones holding obscure plants which the author regards as of Devonian age. Carboniferous rocks similar to those of the "Horton Bluff group" were noted in Antigonish County, and also in Cape Breton.

Mr. Alexander Murray reported in 1873[1] that the boundary of the Carboniferous area of Newfoundland "may be traced from a little north of Cape Ray along the northwest flank of the Long Range of Laurentian Mountains up to the head of St. George's Bay, where it was supposed to cross over and, making a further stretch beneath the marshes to the north, finally sweeps around in a westerly direction and crosses Harry's Brook below Spruce Brook," where it rests on Lower Silurian rocks. It is there interrupted by the Indian Head range, but farther west it again comes to view on the coast of Port à Port Bay, Long Point, and in the valley of the Coal River. The total thickness is about 6,450 feet.

Messrs. Matthew, Bailey, and Ells reported[2] that the Carboniferous rocks of Queens, Sunbury, and part of York Counties are to be considered under three main divisions: "(1) Lower Carboniferous formation; (2) Middle Carboniferous formation; (3) Upper Carboniferous forma-

[1] Murray, Alexander: The Carboniferous series of Newfoundland. Geol. Survey Newfoundland: Report of progress for 1873. Montreal, 1873. Pp. 14–35, 42.

[2] Bailey, L. W., G. F. Matthew, and R. W. Ells. Report on the Carboniferous system of New Brunswick, in the counties of Queens, Sunbury, and a portion of York. Geol. Survey of Canada: Report of progress for 1872–'73, 1873, pp. 180–230.

tion." In addition to the general outline and distribution of this series of deposits previously described[1] the authors, as the result of more recent studies, remarked that the Lower Carboniferous rocks of the coast series show many important differences from the same deposits of the above-named counties. The gray Carboniferous rock of Dawson's "Lower Coal Measures," though seen in the Kennebeccasis Valley, is not known in the central Carboniferous area. The limestones so prominent in Nova Scotia are much limited to small areas in New Brunswick. But the "red sandstones and conglomerates" are numerically prominent in both provinces.

After giving a full account of the distribution and physical characters of the Lower Carboniferous, the authors treated of the Middle and Upper Carboniferous series of the same region in the same manner, describing numerous areas and giving sections of the same, together with notes on the fossil remains. The total thickness of the middle and upper formations is about 600 feet. The total area of the same is about 28,540 square miles. One-third of this area is covered with coarse gray beds forming a part of the "Middle Carboniferous formation." The total area of coal seams is about 112 square miles. This area is probably much larger than the above estimate.

Mr. Charles Robb,[2] in 1873, reported that the Sydney coal field covers about 200 square miles. It is bounded by the Atlantic coast on three sides, and on the fourth (southwest side) by Lower Carboniferous rocks.

Messrs. Huntington and Hitchcock,[3] in 1873, reported that the fossiliferous rocks of northwestern Maine were first noticed by Dr. Jackson, near Parlin Pond, and bowlders of this formation were found scattered to the south as far as the mouth of Kennebec River. Fossils were also noticed at Lake Brassua. The fossils obtained were recognized by Billings as characteristic of the Oriskany sandstone, and subsequently the Cauda-galli grit was recognized on the shores of Moosehead Lake.

In concluding the authors observed that: (1) The Oriskany sandstone, which can not be traced toward the White Mountains, was elevated before the deposition of the Devonian; (2) the thickness of the Oriskany is five times that represented in Pennsylvania, about 2,600 feet; (3) the discovery of Helderberg limestone in new localities indicates an extended submergence of eastern America in Upper Silurian and Middle Devonian times.

Mr. Charles Robb,[4] in 1874, attempted to clear up some of the difficulties

[1] Bailey, L. W., G. F. Matthew, and R. W. Ells: Report on the Carboniferous system of New Brunswick, in the counties of Queens, Sunbury, and a portion of York. Geol. Survey of Canada: Report of progress for 1872–'73, 1873, pp. 204–206.

[2] Robb, Charles: Report on the coal mines of the eastern or Sydney coal field of Cape Breton, Nova Scotia. Geol. Survey Canada: Report of progress for 1872–'73, 1873, pp. 238–290. Map.

[3] Hitchcock, C. H., and J. H. Huntington: Geology of the northwest part of Maine. Am. Assoc., Proc., vol. 22, 1873, part 2, pp. 205–214.

[4] Robb, Charles: Report on explorations and surveys in Cape Breton, Nova Scotia. Geol. Survey Canada: Report of progress for 1873–'74, 1874, pp. 171–178.

culties in regard to the relation of the members of the Productive Coal Measures in various parts of the Sydney field. Accordingly a section extending from the supposed limit of the Lower Carboniferous formation at Point Edward and Sydney to its base is indicated. The rocks consist of red and gray shales, with marls containing nodules of limestone and iron ore. The limestones often hold marine fossils of Lower Carboniferous types, also plant remains, fish scales, teeth, spines, and coprolites. The estimated thickness is about 4,637 feet. On the shore opposite Point Edward the rocks are of the Millstone grit formation. These rocks rest upon massive beds of conglomerate and sandstone, which are prominent in Cape Breton coal fields. In constructing sections of a minute character the author finds that the difficulties are caused by faulting. The rocks at Great Bras d'Or entrance appear to be analogous to the Millstone grit of the English coal fields, consisting of sandstones highly colored by oxide of iron, and occasionally a bluish gray, shaly, and bedded limestone.

In Mr. Brown's section, on the northwest of Sydney Harbor, the coal seams appear to run into the Millstone grit.

Mr. Scott Barlow,[1] in 1874, reported that the rocks of the Spring Hill coal field of Nova Scotia consist mainly of alternate beds of sandstones, blue argillaceous shales, fire clays, and coal seams. On the west slope of the Spring Hill Mining Company a section was run having a total thickness of 516 feet, about 12 feet of which are coal seams. A section is also given to the north of Spring Hill Mining Company's west slope, which has a total thickness of 918 feet 11 inches, of which 25 feet are coal deposits. The characters of the rocks are similar to those of the former section. In the Old Pit, belonging to the same association, the same physical characters already mentioned are maintained, the total thickness found at this point being 624 feet 6½ inches, 36 feet of which are coal seams.

Mr. Walter McOuat,[2] in 1874, reported on the coal fields of Cumberland County. The section specially examined by the author extends from the Chiegnecto and St. George Mines to the post-road from Amherst to Truro. As a result of his observations the following classification was arrived at, exclusive of the Lower Carboniferous rocks, as seen at Black River, given in descending order:

	Feet.
1. Millstone grit, red shale, flaggy sandstone (gray and greenish)	1,800
2. Conglomerate, coarse sandstone, reddish and brownish shales	1,500
3. Middle coal formation, gray sandstone and shale, probably the same as at the Joggins	4,500
4. Upper Coal Measures, gray sandstone with false bedding	1,000
5. Red shale, greenish sandstone, conglomerate, and arenaceous gray limestone	5,000
Total	13,000

[1] Barlow, Scott: Report on the exploration and survey of the Spring Hill coal field, Cumberland County, Nova Scotia. Geol. Survey Canada: Report of progress for 1873–74, 1874, pp. 147–169. Map.

[2] McOuat, Walter: Report on a portion of the coal field of Cumberland County, Nova Scotia. Geol. Survey Canada: Report of progress for 1873–'74, 1874, pp. 163–170. Map.

Dr. Dawson,[1] after giving various views that have been held in regard to the rocks of Prince Edward Island, in 1874 declined to separate the "Red beds" of the lower series from the "newer coal formation." Prof. Geinitz, however, thinks that the fossils show "a decidedly Permian aspect." The author, after a more extended examination of the rocks of East River of Pictou, and in sections west of Caribou Harbor, concludes that "the beds which overlie the coal field of Pictou and extend into Prince Edward Island, and which constitute the upper part of the upper coal formation, have such strong points of resemblance to the lower part of the European Permian that they may be called "Permo-Carboniferous."

In 1876 Mr. Charles Robb reported upon the area recently explored by him, lying along the Atlantic coast and including Cow Bay, Glacé Bay, Sydney Harbor, and Bras d'Or basins. The rocks are referred to the following formations:

I. Carboniferous limestone.
II. Millstone grit.
III. Coal Measures.

The section of Sydney Harbor extending from South Bar to Sydney has a total thickness of 879 feet 7 inches, and is a continuation of the "Millstone grit series" from Victoria Mines to South Bar, Sydney Harbor, having a total thickness for the Millstone grit of 3,275 feet. The rocks consist mainly of fine and coarse sandstones, marls, and limestones, micaceous sandstones, and bituminous calcareous limestones, containing *Sigillaria*, *Lepidodendron*, fish scales, and *Naiadites*.

The "Lower Carboniferous rock" from Point Edward, Sydney Harbor, to Morrison Brook, consisting of yellow micaceous sandstones, red and green marls, calcareo-bituminous shales, and thin arenaceous limestones, has a total thickness of 4,591 feet 10 inches. *Sigillaria* and *Lepidodendron* were found in the shales, while *Brachiopods* and *Encrinites* appeared in the bluish gray limestones.

The section of "Millstone grit" from South Head to Mira Bay has a total thickness of 5,706 feet 8 inches. The rocks are of the same character as in the section given above. The Millstone grit of North Head, Cow Bay, is 537 feet 7 inches in thickness. Plant remains occur in the shales, mainly *Cordaites*, *Asterophyllites*, *Neuropteris*, *Stigmaria*.

The section of Millstone grit from Stubbart Point to Limestone Creek has a total thickness of 4,228 feet 5 inches. The rocks have the same physical characters, except that the coarse conglomerates are more ferruginous than in other sections. Coal seams were noted in the North Head section, varying from a few inches to 8 feet in thickness; the latter includes 18 inches of superior coal. The Millstone grit between Lorway and Sydney Harbor, consisting of argillaceous sandstones, shales, and thin coal seams, has a thickness of 2,619 feet 2 inches.

[1] Dawson, J. W.: On the Upper Coal Formation of Eastern Nova Scotia and Prince Edward Island in its relation to the Permian. Quart. Jour. Geol. Soc., vol. 30, pp. 209-210; Canadian Nat., vol. 7, 1874, new ser., pp. 303, 304.

No definite division line is drawn between the Coal Measures (III) and the Millstone grit. The limit of the Coal Measures in the south, however, "is indicated by the occurrence of angular blocks of coarse sandstone scattered over the surface. The rocks consist of argillaceous shales containing numerous fossil plants, and even large tree trunks; red and green marls containing a few plant impressions and *Naiadites;* sandstones, probably derived from the underlying Millstone grit, containing casts of *Calamites*, *Cordaites*, *Sigillaria*, etc., and forming the most persistent member of the series; and lastly, underclays charged with *Stigmaria ficoides*, and limestones full of organic remains, of which there are some sixteen layers, with thickness varying from one-half inch to 2 feet."

The fossils of the limestones are similar to those of the Joggins section,[1] and are of the genera *Naiadites*, *Cythere*, and *Spirorbis*.

The total thickness of the coal seams in the different subordinate coal basins is as follows:[2]

	Ft.	in.
Cow Bay coal basin	27	5
Glace Bay basin	39	6
Luigan tract	47	
Sydney mines	30	5
Boulardrie	28	9
Cape Dauphin	15	5

In 1877, Mr. Hugh Fletcher[3] reported on explorations made by him in Cape Breton.

The Carboniferous rocks referred to in his report are divided as follows:

1. Carboniferous conglomerates.
2. Carboniferous limestone.
3. Millstone grit.

The "Carboniferous conglomerate," which the author considers as corresponding to the "Bonaventure formation" of Gaspé, is the "Basal conglomerate" of New Brunswick and Newfoundland, rests upon the Lower Silurian slates and sandstones, and has near the Coxheath Hills a vertical thickness of 1,890 feet 11 inches, while from Watson Creek to the above hills it attains a thickness of 2,525 feet, maintains its general character of brick-red color, and is somewhat friable. It consists of reddish, micaceous, friable, and argillaceous sandstone, with bands of marl intermixed, reddish friable conglomerate with interstratified fine-grained pebbly sandstone.

No distinct line can be drawn between the conglomerate and the lime stone. The latter occupies a narrow strip along Sydney River, widens toward Point Edward, extending into the valleys of Ball and Leitch Brooks. A section of this formation from the banks of the Sydney River is given. The maximum thickness is 1,041 feet, 6 inches.

---

[1] See Acadian Geology, pp. 173 181.

[2] Robb, Charles: Report on explorations and surveys in Cape Breton, Nova Scotia. Geol. Survey *of* Canada: Report of progress for 1874–'75, 1876, pp. 166–266, map.

[3] *Fletcher, Hugh*: Report of explorations and surveys in Cape Breton. Geol. Survey Canada: Report *of progress, 1875—'76*, 1877, pp. 369-418, map.

In the Millstone grit, consisting of two synclines, and underlying the Coal Measures to the west of Sydney Harbor, no workable seams of coal have been discovered. The rocks consist mainly of greenish gray and white pebbly sandstone, sometimes falsely bedded with small areas of conglomerate containing *Calamites* and other plants.

Mr. L. W. Bailey and Mr. R. W. Ells,[1] in 1878, reported on the Carboniferous belt of Albert and Westmoreland Counties, New Brunswick. The formations of this area are divided as follows:

1. Metamorphic rocks of pre-Carboniferous age with intrusive syenite.
2. Lower Carboniferous formation, including the "Albert shales."
3. Millstone grit, formation, or lower member of the Carboniferous system.

The "Lower Carboniferous rocks" of Albert County are but the extension of those in Kings County, where they are followed by patches of unconformable gray-rock of the Millstone grit series. The section in Albert County consists of: (1) The "Basal Conglomerate," which is sometimes wanting (thickness unknown); (2) calcareous, bituminous shales, including the "Albert shales;" (3) gray, bituminous, and micaceous oil-bearing sandstone; (4) red and gray argillaceous beds, alternating with conglomerates; (5) red and gray conglomerate, limestone, and gypsum; total thickness, 1,950 feet.

Sections are also given from Pollet River, Mapleton, Baltimore, Albert mines, Belivean, and Taylorville, showing the relation of the different series and the system of faults. The series of Albert shales bears strong resemblance to the Horton Bluff series in its fossil contents, stratigraphical arrangement, and rock materials. The general structure of the Albert mine is outlined, with an account of the physical and chemical characters of albertite, and the proofs given of the vein structure of the Albert mine.

The "Millstone grit formation" is recognized by its gray, and rarely pale purple color, and slight dip. It occurs in the southern part of Albert County, running parallel to the metamorphic hills, and showing evidence of denudation, even before the deposition of the succeeding strata. The gypsum beds, which are quite extensive and pure, vary in thickness from 30 to 50 feet.

Mr. Hugh Fletcher,[2] in 1878, grouped the rocks of Victoria, Cape Breton, and Richmond Counties in the following manner:

Laurentian.....	1. Syenitic, gneissoid, and other feldspathic rocks.
	2. George River limestones.
	3. Lower Silurian rocks.
Carboniferous	4. Carboniferous rocks.
	5. Carboniferous limestone.
	6. Millstone grit.

[1] Bailey, L. W. and Ells, R. W.: Report on the Lower Carboniferous belt of Albert and Westmoreland Counties, New Brunswick, including the "Albert shales." Geol. Survey Canada: Report of progress, 1876-'77, 1878, pp. 351-395, map.

[2] Fletcher, Hugh: Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Survey Canada: Report of progress, 1876-'77, 1878, pp. 402-456, map.

Division 4 occurs most largely developed "in the southward extension of the Sydney Harbor basin, and on the Boisdale and Washabeck Hills." Division 5, which attains its greatest thickness on the Washabeck peninsula, is characterized by prominent beds of limestone and gypsum, accompanied by marls, sandstone, and conglomerate. Division 6 is "found on Sydney River and the eastern shore of Forks Lake, divided from similar deposits in the valleys of the Gaspereaux and Salmon Rivers by the East Bay anticline." Sandstones of this series are found on Boulardrie Island. Plant remains are reported from the sandstones.

Mr. Fletcher, in 1879,[1] reported a series of rocks, supposed to be of Devonian age, as "extending from Loch Lomond to St. Peter's, and reappearing on Isle Madame and in Guysborough and Antigonish Counties." They "bear a very close lithological resemblance to the Cordaite shales and Dadoxylon sandstones of New Brunswick." This series is also accompanied by intrusion of trap, such as Mount Granville and Campbell Hill.

The "Carboniferous conglomerate" was found at Mira Bay overlying the "pre-Silurian felsites." This is followed by limestones, and in turn is overlaid by the Millstone grit. The Carboniferous conglomerate and limestone were observed also at Belfrey Lake, Salmon River, and Grand River Falls, but only as small outliers.

The Millstone grit was recognized near Salmon River, having a dip S. 46° E. 80°. A coal seam was found in these rocks near Catalogue Gut.

According to Messrs. Bailey, Matthew, and Ells in 1880,[2] the Devonian rocks of southern New Brunswick occupy the following areas: (1) A basin east of St. John Harbor extending through the Mispec Valley and northeasterly across the Black River; (2) outcrops on Coal Creek, Canaan River, and North Fork; (3) small areas about St. John and Carleton, with possibly Partridge Island; (4) area east of Spruce Lake; (5) an area extending from Musquash Harbor to Lepreau Harbor, and including the Belas Basin, and a small area from Chance Harbor to Dipper Harbor; also an area in the north of Charlotte County and extending into Queen's County.

The estimated thickness of the Devonian rocks of the St. John Harbor series is 7,500 feet. Fossil remains of plants and insects occur in them. The Lower Carboniferous rocks occur around the head of Grand Lake and in the counties of Sunbury and Queens, on the south edge of the coal basin. They also form the greater part of the valley of the Kennebeccasis Bay and River. Although these beds contain fossils of Devonian types, they still lie unconformably upon the true Devonian

[1] Fletcher, Hugh: Report of explorations and surveys in Cape Breton, Nova Scotia. Geol. Survey Canada: Report of progress, 1877-'78-1879, F, pp. 32. Map.

[2] Bailey, L. W., G. F. Matthew, and R. W. Ells: Report on the geology of southern New Brunswick *embracing* the counties of Charlotte, Sunbury, Queens, Kings, St. John, and Albert. Geol. Survey *Canada*: *Report of progress*, 1878-'79, 1880, pp. 1D 261D. Map.

formation, and their physical characters resemble the Lower Carboniferous rocks, consisting of red and gray conglomerates, brownish red shales, bituminous sandstones, and limestones.

Of the Middle Carboniferous there is considerable evidence that if it had ever attained any degree of development it has since been carried away by denudation, leaving only a shallow deposit in the great Carboniferous basin which underlies the Gulf of St. Lawrence, and which is bounded by the southern shore of the Gaspé peninsula on the north and by the Cobequick Hills and coast ranges of western Cape Breton on the south and east. Coal in thin seams has been discovered in this formation by borings, extending over quite an area. It was found in the Newcastle, Coal Creek, and Salmon River coal basins, having a usual thickness of from 18 to 20 inches. Other small areas were found in South Albert, as far west as Herring Cove; also about Quaco and Gardener's Creek rocks resembling Millstone grit were noticed overlying Lower Carboniferous rocks. A small area was also noted in the north part of Charlotte County.

Messrs. Barton and Crosby,[1] in 1880, reported that the Carboniferous rocks of Massachusetts are an extension of the Rhode Island series, and are mainly found in Narragansett Basin, which lies wholly within Norfolk County. This was determined by President Hitchcock.

These rocks are well developed on the island of Aquidneck, and also form a broad semicircular belt reaching from Warwick and Providence northerly by Valley Falls to Wrentham, in Massachusetts, and thence easterly through Attleborough and Mansfield into Bridgewater.

The rocks of this series consist of a very thick, coarse conglomerate, conglomerates passing into green sandstones about 600 feet in thickness, a series of carbonaceous slates including the true Coal Measures, with few sandstones and red rocks. Very close connection can be traced between the Norfolk belt and those at Wrentham. From a close examination of the Norfolk Basin the author is very doubtful whether coal will be found within its limits.

Dr. J. W. Dawson,[2] in 1882, classified the Paleozoic floras as follows:

I.—*Carboniferous flora:*

(1) That of the Permo-Carboniferous is best seen in eastern Nova Scotia, and is represented by *Dadoxylon*, *Pecopteris*, and *Calamites*.

(2) The coal formation contains the greatest number of species, and is especially rich in *Sigillaria* and ferns. One hundred and thirty-five species have been catalogued from this formation.

(3) Millstone grit: Here the species are limited. *Dadoxylon acadianum* is a characteristic conifer of this formation.

(4) Lower Carboniferous: The floras of this period consist mainly of *Dadoxylon*, *Lepidodendron*, and *Ancimites*.

[1] Crosby, W. O., and G. H. Barton: Extension of the Carboniferous formation in Massachusetts. Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 416-420.

[2] Dawson, J. W.: Comparative view of the successive Paleozoic floras of Canada. Am. Assoc., Proc., vol. 31, pp. 415-417; Canadian Nat., new ser., vol. 10, 1882, pp. 372-378.

II.—*Erian or Devonian flora:*

(1) Upper Erian (Catskill): The subflora is characterized by the genera *Archæopteris* and *Cyclopteris* (ferns).

(2) Middle Erian, corresponding to the Hamilton and Chemung of New York, contain mostly *Dadoxylon*, ferns, and *Lepidodendron*. *Sigillaria* is rare, but *Cordaites* is abundant.

(3) The Lower Erian is characterized by the genera *Prototaxites*, *Arthrostigma*, and *Psilophyton*.

The author also discusses Silurian floras.

Mr. J. F. Whiteaves,[1] in 1882, reported that fish remains had been discovered on the north shore of the Restigouche River, opposite Dalhousie, which prove to be Devonian species. Previously to 1879 these rocks had been considered as Lower Carboniferous.

Mr. R. W. Ells,[2] in 1883, speaking of the geology of Gaspé peninsula, reported that at Grand Pabos, Province of Quebec, Lower Carboniferous rocks are found lying upon Silurian rocks, and east of Little Pabos having a breadth of 2½ miles. Another small area occurs also between Grand River and Brech à Manon. At White Head Carboniferous rocks were noted lying upon Devonian rocks. Rocks of Devonian aspect were found in the vicinity of Black Cape, and also on Bonaventure River. Near Pércé Upper Devonian beds of some magnitude were recognized, lying nearly horizontal. Examination showed that there were three series of Devonian beds: (1) The upper deposit, made up of conglomerates and sandstones; (2) the middle deposit, made up of sandstones, shales, and some conglomerates; (3) the lower deposit, made up mainly of calcareous beds. The upper series has an estimated thickness of 3,000 feet. In a former report (1874) the thickness of the lower member of the Devonian is reported as about 7,036 feet. The series abounds in brachiopods, trilobites, etc., of which a long list is given.

Mr. Edwin Gilpin,[3] in 1884, comparing the Nova Scotian coal fields, says that in the three coal fields of Nova Scotia prominent east and west synclinal folds are noticeable. They are not complicated by faults, except when they come in contact with pre-Carboniferous rocks, as occurs on the south side of the Cumberland coal field. In the Sydney field it appears that the disturbing currents ran in a north and south direction, the materials being derived from the Lower Carboniferous rocks. In the Pictou field a distinctive feature was the formation of a barrier-reef of shingle formed from Millstone grit, back of which accumulated large amounts of argillaceous and carbonaceous sediments. The coal beds, fifteen in number, are situated in the lower part of the section, attaining a maximum thickness of 119 feet, while at Springhill, in

[1] Whiteaves, J. F.: Recent discoveries of fossil fishes in the Devonian rocks of Canada. Am. Assoc., Proc., vol. 31, 1882, pp. 353–356.

[2] Ells, R. W.: Report on the geology of the Gaspé peninsula. Geol. Survey Canada: Report of progress for 1880 '81–'82, 1883, pp. 1DD–32DD.

[3] Gilpin, Edwin: A comparison of the distinctive features of Nova Scotian coal fields. British Assoc., *Report 54th Meeting*, 1884, pp. 712, 713.

the lower 1,000 feet of the Coal Measures, with twelve beds of coal, they attain only a total thickness of 51 feet. The author naturally asks the question whether or not the Cape Breton coal fields may not have had a total thickness equal to the Cumberland and Pictou fields?

Sir W. Dawson,[1] in 1884, commented on ancient land floras, showing how the floras of the Devonian or Erian period and of the Carboniferous period present many points of likeness, and are very distinct from those of succeeding times. The conspicuous families are *Rhizocarpeæ*, *Equisetaceæ*, *Lycopodiaceæ*, *Filices*, and *Coniferæ*. The changes which have occurred since the Carboniferous consist mainly in the degradation of the three first families, and in the introduction of new Gymnosperms and Phænogams, the latter event marking the later Mesozoic age.

In 1885 Permo-Carboniferous rocks were reported by Mr. Ells[2] as occurring between Cape Bald and Bay Verte. Their similarity to rocks of Prince Edward Island was noted. Rocks of the same character, consisting mainly of soft red beds, sandstones, shales, and calcareous conglomerate, were recognized at Cape Brulé and between Shediac and Cocagne Head. The Carboniferous area of New Brunswick is made up of four anticlinals. One is situated between Bathurst and Miramichi; the second from Grand Lake to Richibucto Head and Miminegash; the third passes from Shediac and touches the island near Cape Egmont; the fourth from Cape Tourmantine to Cape Traverse, Prince Edward Island.

Specimens of *Lepidodendron* found by Mr. Joseph R. Perry[3] in a graphite deposit in the coal mine at Worcester, Massachusetts, were referred by Prof. Lesquereux to the very rare species *Lepidodendron acuminatum* of Goeppert, originally from the Carboniferous limestone of Silesia, corresponding to the American "Subcarboniferous." The great disturbance and working over of the rocks containing the Carboniferous deposit has transformed this deposit for the most part into graphite, and in the specimen found the carbon is in the form of graphite, though the scars of the plant are distinctly preserved.

The Sydney coal field, Cape Breton, is about 32 miles in length by 6 miles in width, extending from Big Bras d'Or on the northwest to Mira Bay on the southeast. The four basins of which this field is composed are as follows, according to Mr. W. Routledge[4] (1886):

1. Sydney Mine section, with 25 feet 8 inches workable coal.
2. The Lingan Tract, with 39 feet 5 inches workable coal.
3. Glacé Bay section, with 55 feet 9 inches workable coal.
4. Block House section, with 24 feet workable coal.

[1] Dawson, Sir W.: On the more ancient land floras of the Old and New Worlds. British Assoc., Report 54th Meeting, pp. 738, 739.

[2] Ells, R. W.: Report on explorations and surveys in the interior of Gaspé Peninsula and Prince Edward Island. Geol. Survey of Canada: Report of progress for 1882–83–84, 1885, 1°-34°, maps. (Separate in 1884.)

[3] Perry, Joseph H.: Note on a fossil coal plant at the graphite deposit in mica schist at Worcester, Massachusetts. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 157, 158.

[4] Routledge, W.: The Sydney coal field, Cape Breton, Nova Scotia. Am. Inst. Mining Trans., vol. 14, 1886, pp. 542–560.

In the region of Cobscook Bay Devonian rocks are reported by Prof. N. S. Shaler[1] as lying to east of Moose Island, with nearly uniform eastern dips. The section at Perry *may* contain Subcarboniferous as well as Upper Devonian rocks, but apparently the most important section is bearing the greatest likeness to Devonian rocks, is on Moose Island. Here the black shaly deposits have a thickness of from 1,000 to 1,500 feet.

Mr. Frank D. Adams,[2] in 1887, defining the coal-bearing rocks of Canada, says the coal fields of Canada are confined to Nova Scotia and Cape Breton, where there are three important basins, situated in Cumberland, Pictou, and Cape Breton Counties, respectively. The coal basin in the Cape Breton field extends under the Atlantic Ocean. On account of the imperviousness of the strata overlying the true Coal Measures they can be worked without any difficulty. The deepest seam of the Pictou coal field at the Dalhousie Pit is 36¾ feet in thickness. The coals of Nova Scotia are somewhat less bituminous than those of Cape Breton.

Sir William Dawson,[3] who has contributed so much to the elaboration of the Devonian and Carboniferous formations, in one of his later papers has given his matured conclusions regarding their classification and correlation. He retains the name "Erian" for the Devonian system, following his modified usage of "Erie Division" of the Geological Survey of New York. On the eastern coast this is represented by sandstones and shales, and is compared with the Old Red sandstone of Scotland and England.

The beds abound in fossil plants and locally in remains of fishes. Both plants and fishes are "generically similar to those of Britain;" they are of "estuarian and littoral" origin; and the author considers them divisible into two series, characterized by different genera of these organisms.

The only truly marine portion of the system in the Maritime Province is the lower part, corresponding to the Oriskany of the interior, and this may perhaps be regarded as an equivalent of the Downton sandstones of England.

The subdivisions of the Carboniferous system are described as follows:

1. A lower series corresponding to the Tuedian of the North of England and Calciferous of Scotland both in mineral character and fossils (the Horton series of my later papers).

2. A Carboniferous limestone, associated, however, with gypsum, and marly and red sandstones, but having fossil remains for the most part specifically identical with those of England (Windsor series of recent papers).

---

[1] Shaler, N. S.: Preliminary report on the geology of the Cobscook Bay district, Maine. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 35–60.

[2] Adams, Frank D.: On the coal bearing rocks of Canada. Brit. Assoc., Report 56th Meeting, 1886, 1887, pp. 639–641.

[3] On the Eozoic and Paleozoic Rocks of the Atlantic coast of Canada, in comparison with those of *western* Europe and of the interior of America, by Sir J. William Dawson, K. C. M. G., etc., 1888. *Quar. Jour. Geol. Soc.*, pp. 797–817.

The Erian or Devonian system, p. 813. The Carboniferous system, etc., p. 814.

3. A Millstone grit series consisting of coarse sandstones and shales with conglomerate, mostly of red colors.

4. The Main or Productive Coal Measures, precisely similar in character to those of Britain.

5. A Permo-Carboniferous series, perhaps corresponding in age to the Lower Permian of England, and consisting largely of Red sandstones with species of plants characteristic in Europe of the Lower Permian, but including no limestones.

The conditions of the Carboniferous are on the whole similar throughout North America, except in the extreme West and locally in the Appalachian region; but in Nova Scotia, Newfoundland, and New Brunswick they are more nearly allied to the British type, except in the abundance of red marls and gypsum in the lower part.

CHAPTER XII.

CONCLUSIONS.

When this essay was begun it was thought possible to prepare a thorough paleontologic definition of the systems and series under consideration. The result has demonstrated that the facts are not yet accumulated to make this possible. In the first place, the formations themselves are not delimited on the same basis in different provinces, and, secondly, the fossils have been reported under so many different names that a thorough revision of the several biologic groups is necessary before the various lists prepared can be scientifically correlated. In the meantime such lists as Mr. Miller's "American Paleozoic Fossils" will suffice for all practical purposes. At the outset it was thought that an exhaustive review of all American literature on the Devonian and Carboniferous systems would be profitable. As the research has progressed it has become evident that this literature may be divided into three classes, viz: (1) Records of observations and facts; (2) discussions of the relations and classifications of the facts; (3) controversial literature. Although all the accessible literature has been consulted, I have concluded that the first class can not be abstracted to advantage; that the third class has generally been more concerned in the defense of personal opinions than in the elaboration of the truth, and in many cases the controversy has been occasioned by imperfect understanding of the views of others. For the present essay selection has been made chiefly from the second class of literature, written in most cases by those exhibiting some acquaintance with the immediate local problem under discussion, and also with the opinions of others, and with the corresponding formations in other regions. Another restriction was found necessary: To go into full details would have made a book so large that few would take the trouble to read it, hence whenever practicable formulations of results have been given, leaving the student to examine the original works for details. For these various reasons a large number of the authors consulted, probably a large majority, are not represented here by quotations or title.

The territory discussed may be classified for our purposes into the following geographic provinces: Acadian, Appalachian, Mississippian, Michigan, Western, and Northern provinces. The Acadian province is geologically isolated from the others, and has a history of its own. The facts accumulated for the Northern province, extending from Manitoba

along the Mackenzie River to the Arctic and about the shores of Hudson Bay, are too fragmentary to admit of generalization. The Western province has not been worked up with sufficient detail to admit of other than broad generalizations. The correlations in these three provinces were based upon purely paleontologic data. The other three provinces are partly connected at their boundaries and roughly defined are great basins, in which the more recent Carboniferous formations are partially, at least, surrounded by the older Devonian rocks.

The Appalachian province is separated from the Mississippian province by a geological anticline called the Cincinnati axis, extending from middle Tennessee in a northeasterly direction to near Sandusky, Ohio, and thence across Lake Erie into Ontario, Canada. The Michigan province is connected with both the Appalachian and the Mississippian provinces by a common band of Devonian rocks running from Toledo across to the southern end of Lake Michigan.

In the center of the Mississippian province the Ozark Uplift occupies, with Silurian and Archean rock, the southeastern third of Missouri and parts of adjacent Illinois and Arkansas. The western edge of this province is terminated by the overlying Cretaceous along an irregular westward curving line connecting Omaha and Austin, Tex. The northeastern or Acadian province is defined at the opening of the last chapter and exhibits an immense thickness of Devonian and Carboniferous shales, sandstone, and conglomerates, with little limestone, estimated at 9,500 feet of Devonian and 16,000 feet of Carboniferous. Along the eastern and northeastern borders of the Appalachian the thickness may be a third less, but the deposits are still arenaceous, with some argillaceous shales and with little limestone. The arenaceous deposits decrease on going westward for the whole Devonian until in Iowa the total Devonian is estimated at 200 feet of shales and Magnesian limestone. The Devonian is represented all around the Michigan province by considerable limestone in its early stage, running up into soft shales, then Lower Carboniferous sandstone and shales, and finally a few hundred feet only of Coal Measures. Passing southwestward along the Appalachian province, or from Iowa and Michigan southward in the Mississippian province, the Devonian loses the calcareous base and the arenaceous top and dwindles down to a black shale, varying from one hundred feet or so in Kentucky to nothing in Southern Tennessee and around the western and southwestern margins of the Ozark Uplift. With this change from the complex Devonian formation of New York to the simple black shale of Tennessee there is a corresponding change in the Lower Carboniferous from arenaceous and shaly deposits in Michigan, Ohio, and Indiana to limestones of over a thousand feet thickness in the Mississippian province, separating the black shale from the Coal Measures.

With all these differences in the stratigraphy there are corresponding differences in the faunas and floras, and as the geologists have surveyed

the rocks and brought the facts to light the difficulties of exact correlation have been as great as the complexity of the facts.

In the historical development of the geology the northern part or the Appalachian province was first developed; afterward, and by other men, the Mississippian province was surveyed and interpreted.

Among the numerous problems which American geologists have had to solve, I have selected a few to show the methods employed in correlations and the reasons why one method has led to erroneous and another to correct results. The object of correlation is and has been to bring newly discovered formations into their proper places in already established systematic classifications. Hence in studying the principles of correlation it has been necessary to deal mainly with the classifications. The original classifications may have been founded on wrong principles, and in such cases, however correct the methods of correlation may have been, the results were unsatisfactory. In the first stage of the history this was the case. The Wernerian classification was based on the supposition that the stratigraphic order of deposits and the lithologic composition of the separate members had some natural relation to each other. This is not the fact. It was on this account that all the work of Amos Eaton, in New York State, though based upon careful observation and accurate record of the facts, was a failure so far as the correlations were concerned. After he had perfected the Wernerian system, thoroughly adapted it to our facts, and provided an American translation, so to speak, of the German method, the fallacy of the method was exposed and the whole of his scheme was abandoned. The New York rocks were admirably adapted to the construction of a correct classification of the Paleozoic systems, except for the highest member. For that the adjoining State, Pennsylvania, furnished what New York lacked. For nearly half of the State the dip of the rocks is scarcely greater than 50 feet to the mile, and they are so regular that numerous sections could be easily examined running through the same series of deposits, the local variations noted, and, most important of all, great quantities of fossils were obtained. The result was that the New York rocks for the Silurian and Devonian systems furnished the standard classification for North America, and after 1843 (the date of the completion of the final reports of the geological survey of the State of New York) whatever imperfections might have been detected were easily corrected by reference to the strata themselves. All mistakes in correlations of these formations thereafter were the fault of the method of correlation, not of the classification used.

The Carboniferous rocks of Pennsylvania are mainly arenaceous and argillaceous, and marine fossils are rare in them. The classification that was developed was therefore one based chiefly upon stratigraphic and lithologic characters. Heroic attempts were made to trace the various lithologic units of the system beyond the State; but even from *county to county* in Pennsylvania the modifications were so constant

that correlation became a problem of dip and thinning of the rocks, or of number and thickness of coal-beds or of sandstone strata. The result was that almost every State having Coal Measures had its own classification of details, with the *apparent* symmetry of a lower, a middle, and an upper division. As far as a local coal bed could be traced so far there was correlation. This method of correlation led to the theory of "persistent parallelism of strata," which was applied very considerably in the second Pennsylvania survey, and to some extent in all the Coal-Measure areas. In Pennsylvania this theory was applied, and the resulting correlations were unsatisfactory in proportion to the distance the correlations were carried. It was not, strictly speaking, correlation. It was rather an actual tracing of the strata from outcrop to outcrop by geometrical processes. The correlations were unsatisfactory because in the clastic rocks which there prevail the details of lithologic characters, as composition, fineness, or coarseness of grain and thickness of strata, are not uniform, but vary considerably even in a short distance. Occasionally there were fossiliferous strata in the Coal Measures which gave a clew to the true position in the standard stratigraphic scale.

In the Mississippian province the first attempts at correlation were with European standards. In this case there were two fundamental data upon which the correlations were based. These were the "Coal Measures" and the "Mountain Limestone." The presence of coal beds in association with underclays and sands was taken as evidence of the Coal Measures of the English geologists, and the finding of limestones below these Coal Measures containing fossils determined to be identical with those described from the Mountain limestone of Derbyshire, in Martin's "Petrificata Derbiensia," was the reason for calling the limestone "Mountain limestone." As far as the general correlation was concerned the determination was correct, but when attempt was made to push the correlation to details it was found impracticable to fit either the standard English scale or that already developed in the Appalachian province to these rocks of the Mississippian province. The result was that as the details were accumulated by geological surveys the geologists developed a classification and nomenclature of their own, in the same way that the New York geologists had done for their State. The chief work accomplished in this province was the elaboration of the series between the Devonian and the base of the Coal Measures, called "Subcarboniferous" and "Lower Carboniferous," which is so characteristic of this region that I propose to give it the name "Mississippian series." The discussion of the facts determining the upper limit of the Coal Measures, as seen in the chapter on the Permian Problem of Kansas and Nebraska, may also be considered as one of the results of the study of this Mississippian province.

One of the most instructive illustrations of the principles of correlation is seen in the determination of the base of the Mississippian series.

In this determination two distinct methods of correlation were exhibited. The geologists familiar with the standard sections of the New York system, and of the Appalachian province in general, applied the principle of "persistent parallelism of strata," and, having gone carefully over the ground, believed they had established beyond dispute the correlation of rocks at the base of the Mississippian series with the upper member of the New York Devonian, i. e., the Chemung group.

The "Chemung group" of Iowa and Missouri was originally thus determined, and was defended on this basis for a number of years against the counter evidence of fossils. When the fossils were studied and compared with the fossils of the Chemung of New York they were found to closely agree generically, but specifically there were very few cases of identity. To correct this discrepancy a gradual modification of the species or combination of species constituting the local faunas was assumed to have taken place coordinate with difference in longitude on passing westward. The fallacy in this assumption deceived some of the ablest geologists of the country, and for nearly twenty years general reliance upon their authority stood in the way of the acceptance of the truth.

On the principle of establishing correlation of horizon by identity of the fossils all the evidence went to prove that the so-called "Chemung" rocks of the Mississippi Valley were of Carboniferous age. M. de Verneuil so identified the specimens he saw when on a visit to this country in 1847. D. D. Owen, one of the earliest geologists to study the rocks of this province, and others who followed him, recognized the "Carboniferous aspect" of the fossils. But these identifications of the fossils were not generally accepted as outweighing the other evidence of supposed correlation with Chemung rocks until the year 1861, when Messrs. Meek and Worthen established the Kinderhook group.

The Kinderhook group was the result of pure paleontologic correlation, in which the fauna at the base of the "Carboniferous limestones," often in sandy or shaly strata, was distinctly recognized, by comparison with authentic Carboniferous species of Europe, as of Carboniferous age. The identifications upon which the name was applied were of Illinois fossils; the correlation included led to the correct correlation of the "Goniatite beds" of Indiana, and later of the Waverly group of Ohio, and the recognition of the "Black shales" of the Mississippi province as the termination of the Devonian series. Although the correlation included the faunas of the Chemung of Iowa and Missouri, the application of the name "Chemung" there had become locally fixed to the particular rocks, irrespective of their supposed equivalency, and the name was not immediately dropped. The fundamental error in the Chemung correlation was made near the eastern end, on passing from Chautauqua County, New York, across to Cleveland, Ohio. Passing westward from Ohio the error was not noticeable, so that the identity *of many Ohio* Waverly species with those found in the Western Che-

mung helped to keep up the misinterpretations. Mr. Meek's success in correlations appears to have been due to his minute knowledge of the characters of fossils and their relations to each other, and perhaps still more to his firm faith in fossils as the one reliable guide to true correlation.

The principle of "persistent parallelism of strata" is defective in several ways: (1) Although it has been often observed that a stratum continues for a long distance with but slight variation in thickness and character of material, the constancy of lithologic and stratigraphic character can not be assumed to be the case, even for short distances, unless actually so observed. From this we deduce the law that "parallelism of strata" is not a safe means of correlation, although the correlation once being established, the parallelism of strata is a valuable aid in the recognition of the correlation for detached sections. (2) The errors made by this method of correlation occur at points where the evidence is lacking, therefore it is impossible by merely going over the field a second time to correct such errors. (3) Even when there is apparent continuity of a single stratum or of a series of similarly formed strata, for tens or hundreds of miles, this alone is not evidence that the deposits at the two extremes were formed synchronously. The correct interpretation of the continuity, in case the material is purely clastic, is more likely to be found in a gradual shifting of the shore line by rising or sinking of the land than in synchronism of deposition. On the other hand, the correlation of geologic formation by their fossil contents is (1) Always made upon actual evidence, any errors of interpretation of which can be corrected by critical review of the evidence; (2) the particular form assumed by any organic structure appears to be determined almost entirely by two factors, i. e., heredity and environment; hence we may deduce the law that, given the locality and the conditions of environment, the fossil has in itself the evidence of its geologic age.

The precision with which correlations may be made upon paleontologic evidence is determined by the knowledge possessed of the relations of the elements of organic form to geologic age, so that a fragment of a fossil in the hands of one who knows how to interpret the evidence may furnish a more correct diagnosis of the age of the formation than a bushel of fossils in the hands of one ignorant of the laws of organic life determining the form of the structures produced.

The lowest member of the Mississippian series in Illinois having been defined as the Kinderhook group, it was a matter of simple paleontologic correlation to fix the lower limit in Iowa at the base of the "Chemung group," in Missouri at the base of the formations later called Chouteau group, in Indiana at base of the Goniatite beds, in Ohio at the base of the Waverly, and in Michigan at the base of the Marshall group. Immediately underlying these formations or their evident equiv-

alents in several of the States of the interior a black shale is conspicuously constant. While the black shale was generally correlated as Devonian, its precise age has not up to the present time been certainly fixed.

That the black shale has not been satisfactorily correlated is shown by its retention of that general name in spite of its frequent correlation with other black shales of definite age, as the Marcellus and the Genesee formations of New York.

As the terrane separating Silurian from Carboniferous thins out to the southwest, it is finally restricted to a few feet of black shale, but it is not proved paleontologically precisely what part of the expanded series, called Devonian in New York and Ohio, is represented by this shale.

In the later work of the geologists of Ohio a certain symmetry in correlation is sought by uniting the black shales, up to and including the Cleveland shale, into a single group and calling it the Ohio shale, correlating this as the upper member of the Devonian system.[1]

Prof. Newberry, in his monograph on "The Paleozoic fishes of North America,"[2] classifies the deposits above the last prominent black shale as Carboniferous, thus conforming with the general principle of making the black shale the top member of the Devonian system. In the case of Prof. Newberry this correlation is not new, and was first advanced to make the classification conform to a theoretical order of deposits explained under the name "circles of deposition."[3] But the tendency on all hands has been to accept this structural line of demarkation between the Carboniferous and Devonian formations. Still further work upon the structural as well as the paleontologic features of these black shales will be needed to determine their true correlation.

The subdivision of the Mississippian series is a matter of classification rather than correlation proper. All through the province variations in the stratigraphy are seen in the development of the local geologic structure. The structural or lithologic formations distinguishable over most of the province are as follows:

Chester group, Worthen.	Burlington limestone, Hall.
St. Louis group, Worthen.	Kinderhook group, Meek and Worthen; or
Warsaw limestone, Hall.	Chouteau group, Broadhead.
Keokuk group, Worthen.	

These formations have been defined in their typical localities and the faunas as locally studied have been described, but in several cases difficulty has been experienced in attempting to extend the classification over the whole Mississippian province.

The difficulties have occurred most frequently in distinguishing between Burlington and Keokuk faunas in the formations in western and

[1] Geol. Survey of Ohio, vol. 6, by Edw. Orton, 1888.

[2] U. S. Geol. Survey, Monograph, vol. 16, 1889.

[3] See a theory of circles of sedimentation, by J. S. Newberry, Am. Ass. Adv. Sci., Proc., vol. 22, pt. 2, pp. 185-196, 1873, and on circles of deposition in sedimentary strata, Canadian Nat., new series, vol. 7, pp. 163-164.

southwestern Missouri and northern Arkansas, in distinguishing in some cases whether a fauna is a Warsaw or a St. Louis fauna. The Chester fauna may be associated with particular conditions of environment.

On considering these several facts, it has appeared to the writer that in classifying the formations of the Mississippian series the correlations from a *structural* point of view have been carried too far and that an increase in the number of lithologic formations will better express the facts as at present known; whereas from a *paleontologic* point of view the classification is too minute, and that a combination of some of the formations will best express our present knowledge regarding their true relations. The practical application of this suggestion will result in applying new local names to structural formations whenever the structural characters are so divergent from those of the typical section that the correlation depends upon stratigraphic position above or below some clearly recognized horizon for its validity.

Recent studies of the fossils, their original grouping into local faunas and their association in other parts of the province, have led me to recognize three fairly well differentiated faunas in the Mississippian series, the subdivisions of which are believed to be local, and therefore very unsatisfactory for purposes of correlation.

The following table sets forth the proposed classification and nomenclature:

Structure scale.			Time scale.
Mississippian series	Chester stage		Genevieve age.
	St. Louis stage		
	Warsaw stage		
	Keokuk stage		Osage age.
	Burlington stage		
	Kinderhook stage, including	Chouteau limestone	Chouteau age.
		Vermicular shale and sandstone	
		Lithographic limestone	

The Chouteau age is the age of the Chouteau group of Broadhead. The Osage age is the age of the fauna of the Burlington and Keokuk formations, which are locally distinguishable, but in the sections on the northwestern, western, and southwestern flanks of the Ozark Uplift are so blended that it seems impracticable in most cases to differentiate them. The name is suggested by the fact that the Osage River drains the region in which this confusion of the two faunas is clearly exhibited. The Genevieve age is the age of the fauna of the Archimedes group of Shumard.[1]

The name is suggested by the fact that Shumard first called attention to the union of the several formations in which the common fauna prevails in his description of the geology of Ste. Genevieve County, Missouri. The name he applied was Archimedes group, but this is not a sat-

[1] Repts. Geol. Survey Missouri, 1855–1871, by G. C. Broadhead, F. B. Meek, and B. F. Shumard Ibid., 1873, pp. 292–293, by B. F. Shumard.

isfactory name, and in the county of Ste. Genevieve and on the eastern and northeastern margins of the Ozark Uplift, above and below this county, are found the typical outcrops of the individual formations included in the group.

This classification is used in reports already communicated to the State geologists of Arkansas and Missouri, and I give it here to expose the latest results of my attempts at correlation of these formations.

One of the most important results which such a review of the history of correlation emphasizes is the fact that all attempts to attain uniformity of classification or nomenclature have failed to a greater or less extent.

The extent of the artificiality of the correlation is in some measure proportionate to the distance separating the formations compared; but the experience of the geologists of the second geological survey of Pennsylvania shows how difficult it is to make satisfactory correlations even between the rocks of adjoining counties.

Amos Eaton, seventy years ago, attempted to make the classification and nomenclature of the New York formations uniform with that of Germany and England. He succeeded as well as anyone could in his time; but some young men, trained in his own school, went into the field a few years later to work up the geology of New York State. They began with the application of his system, but when they found it fettering the accuracy of their observations they cast it aside. They recorded the facts as they found them, gave independent names to the formations for the purpose of identifying them, and formed a New York system.

The classification and nomenclature of this system has been adopted as a standard in all respects except where uniformity with European usage was attempted.

The name "system" was lost because this is only part of a system; the divisions, Champlain, Ontarian, Erian, etc., have been discarded because they are purely artificial and have nothing to do with the natural classification of the rocks; the grouping of the formations into Devonian, Silurian, is still allowed, but it is applied both loosely and unsatisfactorily by all except the text-book user. After the New York survey was completed, the same men, satisfied with their success, and still remembering the philosophy of uniformity, thought it might be applied to all American geology. They went westward, tried to fit the New York and Pennsylvania systems to the geology of the Mississippian province. In the cases where they attempted to classify the Mississippian rocks on the Appalachian model the result proved unsatisfactory, because artificial and not expressing the facts as they are. In the cases where the nomenclature and classification have been built up independently and strictly according to the local expression of the facts they have been retained.

One after another of these early attempts to produce uniformity in

nomenclature have been discarded because the facts did not support the correlation when precision was applied. In the far West the anomalies were so great that defenders of the traditional geology have stood aghast. The Government geologists, who were chiefly concerned in developing the facts, have gained the reputation of disregarding precedent, European standards, and even the opinions of their brother geologists; but after one of these doubters has climbed the Rockies, trailed across the plateaus, and looked into the cañons, he has come back forced to confess that "the half was not told him," and paleontologists and geologists alike have been obliged to expand their systems to accommodate these bold geologists of the saddle.

Such has been the result of seeking uniformity for a single continent. Like results, we believe, will appear upon comparison of the formations of different provinces on other continents. The experience of European geologists who have not gone outside Europe has been mainly with the details of a single geologic province; a certain degree of uniformity is therefore practicable for them. It is no disrespect to the European system that has led Americans to think lightly of conformity to any uniform standard of geologic classification or nomenclature. The reason for the failure on the part of American geologists to adopt and apply the older standards of Europe to their formations is found in the fact that the supposed uniformity does not actually exist.

The literature of the first quarter of the century demonstrated that classification can not be based upon *uniformity of lithologic constitution.* The last twenty-five years has made it evident that *uniformity of stratigraphy* can not be relied on for correlations, and now the modern school of paleontologists are demonstrating the fact that the divisional lines marking the biologic or time scale do not correspond to those of the structural or stratigraphic scale, but are determined by independent factors. In the classification of rock formations the character of the formations should receive chief consideration, but the particular geologic period in which sediments are deposited has practically no relation to the nature of the sediments or their amount or their physical arrangement as geologic deposits. It is, hence, a grave question whether the development of our science does not demand that geographic factors should take precedence of time factors in all classifications of geologic formations.

The correlations between form, density, and composition of minerals are formulated in systematic mineralogy, the correlations between form structure and age are formulated in systematic paleontology, and a systematic geology will be attained when the relations between the composition, the stratigraphic order, and the geographic position of rock formation can be adequately formulated.

The experience of geologists in the past shows conclusively that composition and stratigraphic order of sequence are intimately associated with geographic locality. Each geographic province has its own

history and will ultimately require its own nomenclature and classification.

It was Kirwan,[1] I believe, who classified the rocks as "mountains," translating the German word "gebirge" into mountain, instead of formation, as we should do now; thus, "Steinkohlen gebirge," "grauwacken gebirge," he called "Carboniferous mountains," "Greywalcke mountains."

Although the double sense is at once evident to us, the conception of the German geologists expressed in applying the name "Gebirge" to a geologic formation is not so far wrong as at first it would appear. It was long ago learned that uniformity of nomenclature for mountains of different continents is absurd.

Although some relation exists between the position on the continent, the distance from coast, and the size of the adjacent sea, as Guyot has shown, geographic position of a mountain is the one thing distinguishing it from all other mountains, and no consideration of similarity in mountains dispenses with the necessity of separate names for every local mountain range. Although covered from sight, and with our present knowledge difficult to outline, it is altogether probable that geologic formations are as completely separated geographically as are mountains. Any classification of formations which does not recognize geographic position as of primary importance is artificial, and in the nomenclature regard for the geography must find a place if we would be scientifically accurate.

Having defined the geologic formations of a province, their correlation with those of another province can be made only by means of the fossil contents. This the experienced geologist has demonstrated.

History shows that the correlations which have best endured the test of time were made regarding formations whose structural and stratigraphic features were elaborated independently of the correlation, and the correlation of which was based upon carefully collected and exhaustively studied fossils. The records of structure, composition, and stratigraphic order, when based upon careful observation, are permanently valuable contributions to knowledge, and their value is not increased by attempts to fit them into some established classification upon scant paleontologic data or hasty paleontotogic comparison.

The classification made by the field geologist should not be warped to conform to any standard, not even that of the adjoining county, unless there is structural evidence of identity of formations. Correlation by physical means, i. e., inference from general dip, altitude, thickness, when associated with likeness of composition, is practicable for short distances and when made by experienced geologists, but even then the determination is not absolute; contradictory paleontologic evidence in the hands of an equally expert paleontologist should always be given precedence.

[1] "Geological Essays," London, 1799.

The undisputed correlations from one province to another, as from the European sections to those of New York, from the Appalachian to the Mississippian provinces, or from either of these to the Acadian province, rest entirely upon biologic evidence—coal beds and masses of coral and crinoidal limestone are of biologic not geologic origin. Such correlations are generally satisfactory so far as they pertain to the general equivalency of systems or series; but all attempts to correlate with precision the limits of such divisions or to establish uniformity in the subdivisions of two separate provinces has proved forced and artificial, and the history of American geology shows that after the determination of the general equivalence of age, in matters both of classification and of nomenclature, little attempt has been made to attain uniformity with outside standards. Paleontologists have discussed the relations between the fossil faunas of America and the European standards, but the cases have been rare in which the differences have not been as conspicuous as the agreements.

The principles involved in correlations made by use of fossils are purely biologic and are intimately concerned with the laws of structure and growth of the individual, with the effects of environment and geographical distribution, with the laws of heredity and evolution, and with the laws of relationship of organisms to each other and to geologic time. The discussion of these matters would be out of place here; but it may be said that the great advance attained in the accuracy and in the general methods of geologic correlation during the last twenty years is mainly due to the changed conceptions regarding the nature of the organic species.

The Cuvierian notion of species was entirely consistent with the notion of sharply defined, uniform delimitations and "universal" formations. Each species was supposed to belong to one, and how it could appear in two formations was not explained. The Darwinian notion of species is not consistent with sharply defined lines in the classification either of organisms or of formations.

According to this notion the modification of organic form is conceived as not an arbitrary matter, but as correlated with difference of environment and of genetic relationship, so that the lesser variations of specific form are of as great value to the modern paleontologist for purposes of correlation as is the identity of species. Comparison of allied species in the same genus exhibits to him the rate and direction of modification taking place in the genetic history of the genus, and in the plastic or variable characters he finds a sensitive indicator of the stage of development attained by the race when the particular individual lived. Biological study shows him that fossils must contain intrinsic evidence of their geologic age independent of the formations in which they were buried, and his chief work is to learn what this evidence is and how to interpret it. To such evidence the final appeal must be made in all cases of the correlation of geologic formations.

INDEX.

A.

Page.

Acadian province, correlations by J. W. Dawson 209, 210
definition of 226
Upper Paleozoic rocks of 226–257
correlations based on plants of 228
area of 259
Adams, F. D., on Carboniferous of Canada 256
Albert mine, Nova Scotia, J. W. Dawson on 231, 232
Albion coal measures, Nova Scotia 232
Alleghany Mountains coal formations, Edward Miller on 37
Alluvial class of Werner. 15
America and Europe, de Verneuil's comparison of formations in. 67–71
American and European rocks compared, by J. Hall 72–74
American Geological Society, formation of 24
American geologic systems, plan of discussion of 8
Andrews, E. B., on coal plants from Ohio. 92
on Waverly in Ohio 182, 183
on coal fields of Ohio and West Virginia 91, 92
Anvil rock, proposed by D. D. Owen 148
Appalachian basin, paleontology of 65
Appalachian group, proposed. 60
Appalachian province, rocks of 77, 78
conglomerates and Lower Carboniferous of 108–120
area of 259
Archimedes group 169
Arizona, Carboniferous formations of 216
Permian rocks in 221
rocks of Tucson 222
rocks of Grand Cañon 224
Arkansas, L. Bringier on coal in 25
Ashburner, C. A on rocks of Huntingdon County, Pennsylvania 113, 114
correlations of 114
on McKean County Pennsylvania ... 114
Augusta County, Virginia, section 113
Austin Mill, Canada, section 235

B.

Bailey, L. W., on rocks of New Brunswick 244
Bailey and Ells on Carboniferous of New Brunswick 251

Page.

Bailey and Matthew on rocks of New Brunswick 243, 244
Bailey, Matthew and Ells on Devonian rocks of New Brunswick 252, 253
Ballinac Island, rocks of 215
Barlow, Scott, on coal field of Nova Scotia. 248
Barton and Crosby on Carboniferous rocks of Massachusetts. 253
Bath, West Virginia, coal from 99
Beaver County, Pennsylvania, coal measures, I. C. White on. 93
Beaver River and Conoquenessing Creek, Pennsylvania, section 101
Beaver River group, J P. Lesley on 101
Bigsby, J. J., on classification of rocks of Lake Huron. 28
Bituminous coal formation, subdivision of. 139
Black Hills, Dakota, rocks of 199
Boll, Jacob, on Permian of Texas 221
Borré, Ami, nomenclature of 26
Bosanquet, Canada, section 235
Bradley, F. H., on Quebec limestones from Idaho 214
Briggs, C., classification of Ohio rocks 41
Bringier, L., on coal in Arkansas 25
British America, Devonian of 224–225
British Columbia, fossils from 214
Carboniferous rocks in 221
Broadhead, G. C., classification of rocks of Missouri 169–170
on Permian of Kansas and Nebraska. 210–212
Broad Top coal basin, Pennsylvania, J P Lesley on 86
Brongniart, A. T., on fossils 25
on value of fossils in correlation 31
classification of 46
Brown, A. J., on section at Pancake Mountain 216
Brown, Richard, on rocks of Nova Scotia. 228
on Sydney coal field of Cape Breton . 230–231
Burlington, Iowa, section 152–153
C. A. White, on rocks at 157
Burlington limestone, Niles and Wachsmuth on 158–159
area and characteristics of 160
division of, in New Mexico 224

C.

Calvin, S., on Devonian faunas of New York 186
Cambrian, adoption of name 44–45

Page.

Cambrian formation in Wasatch Mountains 218
Canada, J. W. Dawson, on Carboniferous rocks of 245-246
W. E. Logan on formations of 253
J. F. Whiteaves on Devonian rocks of. 254
R. W. Ells, on rocks of 255
Carboniferous rocks of 256
Cape Breton, R. Brown on Sydney coal field 230-231
J. P. Lesley on coal measures of 235-236
Chas. Robb on rocks of 249-250
H. Fletcher on rocks in 250, 251, 252
Cape Dauphin, R. Brown on strata of 230
Carboniferous rocks—
Mississippian province 77
Appalachian province 77-78
Illinois, classification of 160
Arizona 216
Colorado 224
Nova Scotia, Charles Lyell on 230
New Brunswick, C. Robb, J. W. Dawson, Matthew, Bailey, and Ells on, 244-247
Canada, J. W. Dawson on 245-246
Newfoundland, A. Murray on 246
New Brunswick, Bailey and Ells on .. 251
Massachusetts, Barton and Crosby on, 253
Massachusetts, J. B. Perry on 255
Canada, F. D. Adams on 256
Pennsylvania 260-261
Carboniferous conglomerate of Pennsylvania, B. S. Lyman on 86-87
Carboniferous conglomerate, A. Winchell on 179
Carboniferous limestone of Mississippi Valley 153-154
Carboniferous system, confusion in members of 77
history of 75-82
original adoption of term 79
members of 76
Carboniferous and Devonian rocks of Pennsylvania and Ohio, table 119
Carll, J. F., on oil sands of Pennsylvania, 115
on rocks of oil region of Pennsylvania 115-117
names proposed by 115-117
correlations by 115-119
Catskill group, A. Winchell on 121-122
Catskill and Chemung faunas, E. W. Claypole on 128
Catskill and Marshall groups compared .. 181-182
Chagrin Falls, Ohio, section 176
Chance, H. M., on millstone grit of Pennsylvania and England 100
on rocks of Pennsylvania 117-119
classification of coal measure conglomerate 117-118
Chautauqua, New York, section 176
Chemung group, J. Hall on Ohio rocks of, 61-62
correlated with Choteau 147-148
Meek and Worthen on 158
White and Whitfield on Iowa rocks of 158
Mississippian province 262

Page.

Chemung and Choteau groups 190-191
Chemung and Waverly, line of separation between 187
Chemung-Catskill, problem of 121-134
J. Hall on 130
objection to term 131
Choteau group proposed, and described by G. C. Broadhead 170
Choteau and Chemung 147-148, 190
Chester group, flora of 154
Christy, D., on Goniatite limestone of Rockford, Indiana 145
Cincinnati axis, condition in Devonian period 136
cause of difference of sedimentation .. 155
Cist, Z., on coal mines of Wilkes-Barre, Pennsylvania 26
Clapp, A., correlations by 47
Classification, early names in 18
Classification of New York rocks by various authors 57
Claypole, E. W., classification of rocks of Pennsylvania 131
on Catskill and Chemung faunas 128
Cliff formation, D. D. Owen on 141
Coal fields of Ohio, Pennsylvania, and West Virginia, compared 89-92
Coal formations of United States, H. D. Rogers on 85
Coal measures or Pennsylvania series 83-107
Coal measures of Ohio, J. S. Newberry on. 87
Coal measures and conglomerate of West Virginia, W. M. Fontaine on 87-88
Cobscook Bay, Maine, N. S. Shaler on Devonian rocks of 256
Colorado, T. B. Comstock on rocks of San Juan County 223-224
Comstock, T. B., on rocks of San Juan County, Colorado 223-224
Conrad, T. A., classification by 39, 45, 50
correlation by 39-40
fossils of transition 43
on Silurian and Devonian systems ... 50-52
on fossils in classification 51
Connecticut River, E. Hitchcock on formations of 26
Connellsville, Pennsylvania, section 95-96
Conglomerate measures, subdivisions of. 109
Conglomerate series proposed by W. M. Fontaine 93
Conglomerates and lower Carboniferous of Appalachian province 108-120
Conoquenessing sandstone proposed 101
Conybeare, W. D., on Carboniferous system 75-76
on systems of rocks 78
Conybeare and Phillips on value of organic remains in determining formations 28
Cornelius, E., classification of 23
Correlation, principles of ... 11-12, 133-134, 268-269
methods of 12
use of fossils in 12, 21
early attempts at 18

Page.

Correlation, principles of—Continued.
New York with western rocks..... 59
J. Hall, rocks of east and west..... 61–67, 67, 72–73
H. D. Rogers, rocks east and west.... 63
D. D. Owen, rocks east and west..... 64
American and European rocks by de Verneuil 67–71
use of fossil plants in..... 103
Venango, how made 111
Carboniferous rocks of Pennsylvania and Ohio..... 119
Pennsylvania survey 113–124
use of lithology and paleontology in.. 126
Mississippi valley, by J. Hall..... 149–150
various factors in..... 173–174
Mississippian province....171-172, 261–262, 265
American and European Permian.... 195
Nova Scotia coal formations, by L. Lesquereux 237–239
objects of..... 260
paleontologic evidence..... 263–265
from structure..... 265
A. Eaton on..... 266
Cox, E. T., on rocks about Tucson, Arizona 222
Cragin, F. W., on Permo-Carboniferous of Kansas..... 212

D.

Dawson, G. M., on rocks of British Columbia..... 221
Dawson, J. W., correlations in Acadia... 209–210
on Carboniferous system of Acadia.. 226–227
on rocks of Nova Scotia.....228–229, 231
classification of rocks of Nova Scotia.. 232–234
on comparisons of coal measures of Nova Scotia and United States... 236
on species of Devonian and Carboniferous 236–237
on deposition of coal strata..... 239–240
on rocks near St. John, New Brunswick 240
on Canadian Carboniferous rocks.... 245–246
on rocks of Prince Edward Island..... 249
on Paleozoic floras.....253–254, 255
on classification of Devonian and Carboniferous rocks..... 256–257
De la Beche, classification of..... 34
Devonian, Sharp's classification of..... 66–67
de Verneuil on..... 70
confusion of members of..... 76–77
of Pennsylvania, J. J. Stevenson on. 124–125
faunas of.....128–130, 186
classification of 131–134
Colorado 223
Montana 224
British America..... 224–225
New Brunswick 227, 252–253
Maine, C. H. Hitchcock on..... 240
New Brunswick, Matthew, Bailey and Hartt on 240–241
Canada, J. F. Whiteaves on 254
Maine, N. S. Shaler on 256

Page.

Devonian fauna of New York 127, 128–130, 186
S. Calvin on..... 186
Devonian period, Mississippi province in. 136–137
Devonian and Carboniferous, line of separation of 174–175, 178
western and northern provinces..... 213–225
America, Chas. Lyell on..... 229–230
J. W. Dawson's classification of..... 256–257
Devonian and Carboniferous plants of Nova Scotia..... 236–237
Dewey, C., on rocks of New York 42–43
Doornik, J. E., on fossil remains..... 31
Drake, D., on classification 23
Dutton, C. E., on Permian in Utah..... 220
Dyas and Trias, J. Marcou on 200
Dyas in America, J. Marcou on 202

E.

Eaton, Amos, classification of. 19–20, 24–25, 33, 46–47
system of naming rocks..... 27
on Erie canal rocks 27
geological nomenclature of North America 29–31
on coal formation in New York 32–33
correlation of New York rocks 34–35
on correlation of coal beds of Pennsylvania with those of Europe ... 36
correlations by..... 266
Ells, R. W., on rocks of Canada..... 255
Emmons, E., classification of..... 56
Engelmann, H., on Subcarboniferous groups of Mississippi valley..... 163
Erie Canal rocks, A. Eaton on..... 27

F.

Falls of the Ohio, sections..... 151, 176
Faunas, how modified by conditions..... 127–128
Featherstonhaugh, G. W., classification of 35–36
on coal deposits..... 38
Fletcher, Hugh, on rocks of Cape Breton. 250, 251, 252
on rocks of Nova Scotia..... 251–252
Fontaine, W. M., on conglomerate of West Virginia 87
on Coal Measures of West Virginia.. 87–88
proposes Conglomerate series..... 93
on Vespertine of Virginia 112–113
Fontaine and White, on fossil plants of Pennsylvania 102–103
Formations, nomenclature of..... 9
Fossils, use of, in correlations..... 12, 31
identification of geologic deposits by. 18
Fossil plants in correlation 103
Foster, J. W., on rocks of Ohio 177
Frazer, P., on coal from Bath, West Virginia..... 99

G.

Geinitz, H. B., on fossils from Kansas and Nebraska 202
on fossils from the Dyas..... 205
Genevieve group proposed..... 169

	Page.
Geographic provinces, limits of	258–259
Geologic systems, plan of discussion of	8
Geological opinion prior to 1835	13–21
Georgetown, Pennsylvania, section	125
Gibson, J. V., classification of	36
Gilbert, G. K., on rocks of Rocky Mountains	215–216
on Permian of Rocky Mountain region	222
Gilpin, Edward, on Nova Scotia coal field	254, 255
Goniatite limestone of Rockford, Indiana	145, 189–190, 191
Grammar, John, on coal mines near Richmond, Virginia	23
Grand Cañon of Arizona, rocks of	224
Granger, E., on vegetable impressions from Ohio	25
Granwacke	19
Greenbrier River, Virginia, section	112
Greene County, Pennsylvania, section	116

H.

Hague, A., on Eureka district, Nevada	222–223
Hale, J. M., on Coal Measures of Pennsylvania	86
Hall, James, classification of New York rocks	40, 57
on Chemung of Ohio	61, 62
on correlation of rocks of east and west	61–63, 67, 72–73, 155
on Waverly of Ohio	62–63, 177
on Subcarboniferous in Ohio	62–63
review of de Verneuil on strata of America and Europe	68–71
on parallelism of Paleozoic rocks of Europe and America	72–74
on Catskill and Chemung in New York	121–123
parallelism of rocks of eastern and western New York	122
on Catskill Mountain rocks	122–123
on work of J. J. Stevenson	125–126
on Chemung-Catskill faunas	130
on rocks of the Mississippi Valley	149–150, 152–154, 155
on classification of Carboniferous rocks of Iowa, Illinois, and Missouri	154
on goniatite limestones of Indiana	189
Hamilton, Pennsylvania, section	124
Hartley, Edward, on Picton coal field	241 242
Hawn, section of Permian of Kansas	197–198
Hayden, F. V., on Permian of Kansas	205
on rocks of Rocky Mountain region	213–214
Hayden and Meek, on Permian of Kansas	197, 198
Hayes, G. E., on rocks of western New York	38
Herrick, C. L., on Waverly problem in Ohio	187–188
on classification of rocks of Ohio	188
Hicks, L. E., on Waverly of Ohio	184–185
on Permian rocks of Nebraska	212
Hildreth, S. P., classification by	38
Hill, F. A., on coal fields of Pennsylvania	106
Hitchcock, C. H., on coal beds of New England	234
on Devonian rocks of Maine	240
on corals of New Hampshire	243
Hitchcock, Edward, classification by	26
on geology of Massachusetts	35
notice of address by	47–49
Houghton, Douglass, on coal formations of Michigan	41
succession of rocks in Michigan	175
Hubbard, O. P., classification of New York rocks	45–46
Huntingdon County, Pennsylvania, section	113–114
Huntington and Hitchcock, on rocks of Maine	247

I.

Idaho, Spergen Hill fossils from	167
Illinois, classification of rocks of	159–163
Illinois River, C. U. Shepard on rocks of the Upper	42
Indiana County, Pennsylvania, fossils in	97
Indiana, Ohio, and Kentucky formations compared by D. D. Owens	139
Iowa, Subcarboniferous rocks of	146
rocks of, compared with those of New York	153
C. A. White's classification of rocks in	166
Iowa and Wisconsin, formations in	139–140
Ithaca shales fauna in New York	127

J.

Jackson, C. T., on rocks of Massachusetts	38
on determining the age of rocks	44
Jameson, classification of rocks	16–17
Jewett, E., on Old Red sandstone in New York	121

K.

Kanawha Valley, West Virginia, J. J. Stevenson on coal fields of	88–89
Kansas, H. B. Geinitz on fossils from	202
G. C. Swallow on fossils from	205
Permian of	193–212, 207–209
section of Permian rocks in	194
F. V. Hayden on Permian of	205
Kansas River section	206
Kentucky, Owen and Norwood on rocks of	142–143
King, Clarence, on fortieth parallel rocks	217–220
Kinderhook group, proposed by Meek and Worthen	161, 191
how established	262
King, H., on rocks of Missouri	144–145

L.

Lake Huron, classification of rocks by J. J. Bigsby	28
Lea, I., on foot-prints in Pennsylvania	86
on rocks of Prince Edward Island	234

Page.

Lehmann on classification of strata 46
Lesley, J. P., on rocks of Virginia 86
on Broad Top coal basin, Pennsylvania 86
classification of rocks of Ohio, Pennsylvania, and New York 90-91
scheme of classification by 92
on geological explorations in Pennsylvania 94
scheme of formations of Pennsylvania 97
on Beaver River group 101
on Pittsburg coal region 104-106
on coal field of Glace Bay, New Brunswick 227
on coal measures of Cape Breton 235-236
Lesquereux, L., classification of formations 103-104
on correlations of Nova Scotia coal formations 237-238
Lewis Tunnel, Virginia, section 112-113
Lithologic character of rocks, use of, in correlation 111-112, 191-192
use of, in classification 165-166
Litton, A., on well boring at St. Louis ... 157
Locke, John, classification of 41
classification of Ohio rocks 140
Lodore group described 217
Logan, W. E., on Canadian formations 235
Lonsdale, classification by fossils 20-21
Lower Carbonic, J. J. Stevenson's classification of 120
Lower Carboniferous of Pennsylvania ... 108-120
Lower Carboniferous formations of the Mississippi Valley 135-172
Lyell, Chas., on rocks of Nova Scotia ... 228, 229, 230
on Devonian and Carboniferous of America 229-230
Lyman, B. S., on Carboniferous conglomerate of Pennsylvania 86-87
Lyon, S. S., on rocks of Mississippi Valley. 155-156

M.

Maclure, W., classification by 22-23
remarks on work of 24
on Werner's five classes 28
eulogized by B. Silliman 49
Maillet, de, theory of 14
Maine, Devonian rocks of 240, 247
N. S. Shaler on rocks of 256
Mansfield, Massachusetts, C. T. Jackson on rocks of 38
Marcou, J., on Permian 200
on Dyas and Trias 200
on Nebraska City section 201, 202
Marsh, O. C., on vertebræ from Nova Scotia 234
Marshall group, A. Winchell on ... 178-179, 181, 182
Massachusetts, E. Hitchcock on geology of 35
Barton and Crosby on Carboniferous rocks of 253
J. B. Perry on coal field of 255
Matthew, G. F., on rocks of New Brunswick 238-239

Page.

Matthew, Bailey, and Ells on Carboniferous rocks of New Brunswick 246-247
Matthew, Bailey, and Hartt on Devonian of New Brunswick 240-241
Mather, W. W., classification of 40, 55
McCharles, A., on Devonian of British America 224-225
McKean County, Pennsylvania, rocks of.. 114
Meade, W., on anthracite of Pennsylvania 29
Meadville group, members of 110
Meek, F. B., on rocks of Missouri 147
on Spergen Hill fossils 166-167
on Permian fossils of Kansas 193
fauna and rocks of Permian in Nebraska 206-207
on fossils from British Columbia 214
review of H. B. Geinitz on fossils from Kansas, etc 202-204
Meek, F. B., and Hayden, F. V., on section of rocks of Kansas Valley 194-195, 197
on fossils from Permian of Kansas ... 198
on Black Hills of Dakota 199
on Permian of Kansas 200-201
Meek, F. B. and Worthen, A. H., on Chemung 158
classification of 161-162
on Goniatite beds of Indiana 190-191
McOuat, Walter, on Nova Scotia coal field 248
Michigan, coal formations in 41
D. Houghton's succession of strata in 175
A. Winchell on rocks of 177-178
Miller, Edward, on coal formations of Alleghany Mountains 37
Millstone grit of Pennsylvania and England compared 100
Minnesota, classification of Carboniferous rocks in 167-168
Mississippi limestone series of Winchell 179-180
Mississippi Valley, T. Nuttall on rocks of 25, 137
D. D. Owen on rocks of 137-144 145-146
Owen and Shumard on fossils of..... 144
rocks correlated by J. Hall 149-150
rocks of, compared with those of New York 185
H. Engelmann on Subcarboniferous of 163
Mississippian province, rocks of..... 77
sedimentation of..... 135-137
area of 259
correlations in..... 261-262, 263
Mississippian series, name proposed..... 135
rocks of..... 135-172
classification of 169
divisions of..... 263-264, 265
Missouri, H. King on rocks of..... 144-145
generalized section of rocks of..... 147
F. B. Meek on rocks of..... 147
G. C. Swallow on rocks of..... 151
Swallow and Meek on rocks of..... 157
B. F. Shumard's classification of rocks in..... 168-169
G. C. Broadhead's classification of rocks in..... 169-170
Missouri and Iowa coal field..... 144
Montana, Devonian rocks of 224

	Page.
Mountain limestone, subdivisions of	139
Morris, S. Fisher, on New River, West Virginia, coal field	99
Morse, J. O., on Wernerian system	32
Murchison, R. I., classification of	43-44
on Permian	194-200
Murchison and Sedgwick on Carboniferous system	76
Murray, Alex., on Carboniferous rocks of Newfoundland	246

N.

Nebraska, Permian of	193-212
Dyas rocks in	204-205
L. E. Hicks on Permian of	212
Nebraska City section	201-202
Nevada, A. Hague on rocks of Eureka district	222-223
Nevada limestone	223
Newberry, J. S., on coal measures of Ohio	87
on Permian rocks of Kansas	199
correlations of	217
on rocks of New Mexico	217
New Brunswick, J. P. Lesley on rocks of	227
G. F. Matthew on rocks of	238-239
J. W. Dawson on rocks of	240
Devonian rocks of	240-241, 252-253
C. Robb on rocks of	242-243
Bailey and Matthew on rocks of	243-244
L. W. Bailey on rocks of	244
C. Robb on Carboniferous rocks of	244-245
Matthew, Bailey, and Ells on Carboniferous rocks of	246-247
Bailey and Ells on Carboniferous in	251
New England, C. H. Hitchcock on coal beds of	234
Newfoundland, Alex. Murray on rocks of	246
New Hampshire, C. H. Hitchcock on corals in	243
New Mexico, Permian rocks in	199-200
Burlington limestone in	224
New River, West Virginia, Carboniferous rocks on	88
conglomerate on	93
coal field of	99
New York, coal formation in	32-33
D. Thomas on rocks of	34
G. E. Hayes on rocks of western	38
C. Dewey on rocks of	42-43
E. Emmons' classification of rocks of	56
O. P. Hubbard's classification of rocks of	45-46
W. W. Mather's classification of rocks of	55
L. Vanuxem's classification of rocks of	56
J. Hall's classification of rocks of	57
New York State survey, nomenclature of	42
work of	48-49
New York system 39, 52, 53, 54, 55-57, 58-60, 260, 266	
correlated with rocks of the west	59
D. D. Owen's tabulation of	64
de Verneuil on	68-69
Niles and Wachsmuth on Burlington *limestone*	158-159
Nomenclature of formations	9
system of New York geologists	54-55
imperfections of	60-61
system of H. D. and W. B. Rogers	65-66
uniformity in	266-269
basis of	267
Norwood, J. G., on Permian of Kansas	196, 201
Nova Scotia, rocks of	228-230
J. W. Dawson on rocks of	231-234, 236-237
O. C. Marsh on vertebræ from	234
L. Lesquereux on rocks of	237-238
Scott Barlow on coal field of	248
H. Fletcher on rocks of	251-252
coal field, W. McOuat on	248
coal field, Edwin Gilpin on	254-255
Coal Measures	210
Nuttall, T., on structure of Mississippi Valley	25, 137

O.

Ohio, E. Granger on vegetable impressions from	25
classification of rocks of	41
C. Whittlesey on rocks of	43
A. Roy on coal field of	94
classification of Coal Measures in	101-102
J. Locke on classification of rocks of	140
J. W. Foster on rocks of	177
Waverly series in 177, 182, 183, 184-185, 187-189	
M. C. Read on rocks of	183
Carboniferous system in	184
L. E. Hicks on Waverly in	184-185
Edward Orton on Waverly in	185-186
C. L. Herrick's succession of strata in	188
E. Orton's classification of rocks in	188-189
J. S. Newberry on Coal Measures of	87
Ohio River, section on	138
Oil lake group, members of	110
Oil and gas, Edward Orton on	186
Orton, Edward, on Coal Measures of Ohio	102
on the Waverly of Ohio	185-186
on oil and gas	186
classification of rocks of Ohio	188-189
Owen, D. D., classification of	41, 138-141
on Subcarboniferous	63
correlation of rocks of east and west	64
table of New York System	64
on rocks of Mississippi Valley 137-144, 145-146	
on cliff formation	141
section of Subcarboniferous rocks of Iowa	146
on Saint Louis limestone	150
Owen and Norwood on rocks of Kentucky	142-143
Owen and Shumard on fossils of Devonian and Carboniferous of Mississippi Valley	144

P.

Paleozoic suggested by Sedgwick	20
Paleozoic floras J. W. Dawson's classification of	253-254
Paleozoic formations, classification by J. Phillips	20

Page.

Paleozoic formations, etc.—Continued.
H. D. Rogers on 65–66
of America, de Verneuil on 71
classifications by F. Platt 94–95
of the Mississippi Valley 152–154
of Rocky Mountain Region 218–225
of Wasatch and Nevada 230
Paleozoic rocks of Nevada 222–223
of Acadian Province 226–257
Pancake Mountain, section 216
Parallelism of strata, doctrine of 261, 263
Peale, A. C., on Devonian of Montana 224
Pennine Carboniferous System defined 81
use of term in America 81–82
Pennine Chain, rocks in 78–79
section in 79–80
Pennine System proposed 81
Pennsylvania, W. Meade on anthracite from 29
H. D. Rogers on rocks of 42
H. D. Rogers's classification of rocks of 83–85
Coal Measures of 83–107
I. Lea on footprints in 56
Carboniferous conglomerate of 86–87
geological explorations in 94
J. P. Lesley's scheme of formations of. 97
fossil plants of, by Fontaine and White 102–103
F. A. Hill on coal fields of 106
I. C. White on rocks of 108–112
J. J. Stevenson on Devonian of 124–125
E. W. Claypole's classification of rocks in 131
Carboniferous rocks of 260–261
Pennsylvania Coal Measures, J. M. Hale on 86
Pennsylvania survey, correlations by 123–124
Permian, early views as to relations to Carboniferous 79
Kansas and Nebraska 193–212
table of, in Kansas 198
Kansas 207–209
C. A. White on fauna of 210
Nebraska, L. E. Hicks on 212
Utah 220, 221
Texas 221
Rocky Mountain region 221–222
Kanab Valley, Arizona 221
Permo-Carboniferous of Kansas 212
Perry, J. B., on coal fields of Massachusetts 255
Phillips, John, classification of Paleozoic strata 20
Picton coal field, E. Hartley on 241–242
Pierce, J., on coal in Virginia 29
Pittsburg coal region, J. P. Lesley on 104–106
Plateau provinces, J. W. Powell on rocks of 216–217
Platt, F., classification of Paleozoic formations 94–95
on probable sequence of formations of well in Greene County, Pennsylvania 69

Page.

Platt F., classification of, etc.—Cont'd.
new names proposed by 96
on fossils in Indiana County, Pennsylvania 97
Poole and Dawson on Albion Coal Measures 232
Portage=Waverly of Ohio 62–63
Pottsville conglomerate, subdivisions of. 100
Powell, J. W., sediments of Plateau provinces 216–217
on Permian in Rocky Mountain region 223
Primitive rocks of Jameson 16
Prince Edward Island, I. Lea on rocks of. 234
J. W. Dawson on rocks of 249

Q.

Quebec limestones from Idaho 214
Quinnemont beds proposed 97

R.

Read, M. C., on rocks of Ohio 183
Recurrence of faunas, doctrine of 127–128
Red sandstones, position of, in America and Europe 27
Red Wall group described 217
Rhode Island, Pennsylvania, etc., B. Silliman on coals of 29
Richardson, J., on rocks of Ballinac Island 215
Richmond, Virginia, J. Grammar on coal mines of 23
R. C. Taylor on coal field of 37
Robb, Charles, on rocks of New Brunswick 242–243, 244–245
on Sydney coal field 247, 248
on rocks of Cape Breton 249–250
Rocky Mountain region, during Carboniferous time 153
Carboniferous and Devonian rocks of 213–225
Rocky Mountain Paleozoic rocks, C. King on 217–220
Rocky Mountains, C. A. White on rocks of 221–222
Rogers, H. D., system of classification 42
on rocks of Pennsylvania 42
correlation of rocks east and west 63
on Paleozoic formations 65–66
scheme of classification of rocks of Pennsylvania 83–85
on coal formations of United States 85
Rogers, W. B., on passage from Devonian to Carboniferous fauna 157–158
on correlation of rocks of Mississippi Valley 158
Rogers Brothers, on use of fossils 49
nomenclature of 65–66
Routledge, W., on Sydney coal field 255
Roy, Andrew, on Ohio coal field 94

S.

Safford, J. M., classification of rocks of Tennessee 164–166

Page.

Saint Genevieve County, Missouri, section 168–169
Saint Louis limestone 150
Saint Louis, Missouri, well boring at 157
Secondary or Floets limestone of Jameson 16–17
Sedimentation of eastern and western States 171–172
Sedimentation, variations in 174
Sedimentation of Permian rocks in Acadia 210
Sedimentation of Devonian and Carboniferous 259
Selin's Grove, Pennsylvania, section 125
Shaler, N. S., on Devonian of Maine 256
Sharon conglomerate described 109
Sharp, D., classification of the Devonian. 66–67
Shenango, members of 109
Shepard, C. U., on rocks of the Upper Illinois River 42
Sherwood and Platt, correlations by 99–100
Shumard, B. F., classification of rocks of Ste. Genevieve County, Missouri. 168–169
correlation in Kansas 198–199
on Permian of New Mexico 199–200
Silliman, B., on the coals of Rhode Island, etc 29
on use of fossils in correlation 35
on work of W. Maclure 49
notice of address by 49–50
Silurian, adoption of name 44–45
Smith, W., on fossils in identifying strata 18
South Joggins, Nova Scotia section.. 227, 232, 240
Spergen Hill, Indiana, fossils of 166–167
Spergen Hill fossils from Idaho 167
Springer, F., on Burlington limestone in New Mexico 224
State surveys, where and by whom conducted 48
Stevenson, J. J., on coal fields of Ohio, Pennsylvania, and West Virginia. 89–90
on coal fields of Kanawha Valley, West Virginia 88–89
on formations of Pennsylvania 98–99
correlations by 99
classification of Upper Carbonic 106–107
on Umbral and Vesportine strata 119–120
classification of Lower Carbonic 120
on Devonian rocks of Pennsylvania. 124–125
Stilson, W. B., correlation by 24
Subcarboniferous, J. Hall on, in Ohio 62–63
D. D. Owen on 63, 138
use of term 142
subdivisions of 148
Subcarboniferous, A. H. Worthen on Illinois rocks of 148–149, 160
Subconglomerate, divisions of 109
Swallow, G. C., on rocks of Missouri 151
on Permian fossils from Kansas .193, 195, 199, 205, 206
Swallow and Meek on rocks of Missouri. 157
Swallow and Hawn, Permian section of Kansas 194, 195, 197
Sydney coal field, C. Robb on 247, 248
W. Routledge on 255
System in classification defined 80

T.

Page.

Taylor, Richard, on coal deposits and fossils of Pennsylvania 36
Tennessee, G. Troost on rocks of 37, 41
J. M. Safford's classification for 164–166
Tenney, Sanborn, on corals from Wasatch Mountains 214
Tertiary of Werner 15
Tertiary deposits of New York, T. A. Conrad on 39
Texas, Permian in 221
Thomas, D., on rocks of New York 34
Transition rocks of Jameson 16
Troost, G., on rocks of Tennessee 37, 41
on organic remains in the Mississippi Valley 37–38
Tucson, Ariz., E. T. Cox on rocks of 222

U.

Umbral and Vespertine strata, J. J. Stevenson on 119–120
Upper Carbonic, J. J. Stevenson's classification of 106–107
Upper Carboniferous sections in Rocky Mountains 215–216
Utah, Permian in 220–221

V.

Vanuxem, L., on value of fossils in correlation 31–32
nomenclature of 40
on classification of rocks of New York 56
Vanuxem and Mather, classification of 53
Venango correlated with Chemung 110
J. P. Lesley on 111
Verneuil, Edward de, classification by 44
correlation of rocks of America and Europe 67–71
on New York system 68–69
on Devonian of America 70
on Paleozoic formations of America 71
on rocks of Mississippi Valley 143
Vespertine strata of Virginia, W. M. Fontaine on 112–113
Virginia, James Pierce on coal in 29
J. P. Lesley on rocks of 86
W. M. Fontaine on Vespertine strata of 112–113
Volcanic class of Werner 15

W.

Walcott, C. D., on Permian in Utah 220–221
on Kanab Valley, Arizona 221
on rocks of Eureka District, Nevada. 222
on Devonian fossils from Montana 224
on rocks of Grand Canon, Arizona 224
Wasatch limestone 218–219
Wasatch Mountains, corals from 214–215
section in 218 220
Waverly in Ohio 62–63, 177, 182, 183, 184–185, 187–189
Waverly problem 173–192
Waverly series, de Verneuil on 70

	Page.
Way, J. M., on fish remains from New York	121
Waynesburg, Pennsylvania, probable sequence of rocks in well of	96
Weber quartzite	219
Werner, A. G., system of	14
classification of	15–16, 19, 28, 77, 260
Wernerian school of geology	13
Wernerian system of classification	15, 16, 19, 28, 77, 260
Wernerian system, remarks on	32, 38
West Virginia, W M. Fontaine on coal measures of	87, 88
White, C. A., on rocks at Burlington, Iowa	157
classification of rocks of Iowa	166
on fauna of so-called Permian	210
on rocks of Rocky Mountain region	221, 222
White, I. C., on coal fields of West Virginia and Pennsylvania	90
on Beaver County, Pennsylvania, coal measures	93
on formations of Pennsylvania	101
on Lower Carboniferous of Pennsylvania	108–112
correlations of	110
White and Whitfield on Chemung of Iowa	158
White and Whitfield on changes between rocks of East and West	191–192
Whiteaves, J. F., on Devonian rocks of Canada	254
Whitfield, R. P., on fossils from Wasatch Mountains, Utah	214–215
White Pine shale	223
Whittlesey, C., classification of Ohio rocks	43
table of succession of strata	176
Wilkes-Barre, Pennsylvania, on coal mines near	26
Williams, H. S., on Hamilton fauna in New York	127
Winchell, A., on Catskill in New York	121–122
correlations of	122
on Mississippi series or group	136
on rocks of Michigan	177–178
table of equivalents of strata	182
Winchell, N. H., classification of Carboniferous rocks in Minnesota	167–168
Woodward, H. B., on rocks of Pennine chain	79
Worthen, A. H., on Subcarboniferous of Illinois	148, 149
on flora of Chester group	154
on rocks of Illinois	160–163
correlations of	161
Y	
Young, C. A., on conglomerate of New River, West Virginia	93

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 81

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

CORRELATION PAPERS

CAMBRIAN

BY

CHARLES DOOLITTLE WALCOTT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

CONTENTS.

	Page.
Letter of transmittal	13
Outline of this paper	15
CHAPTER I. Introductory	17
Literature	19
List of authors and year of publication	19
List of papers by dates	22
CHAPTER II. Historical review of the geologic and paleontologic work	49
Atlantic Coast Province	50
Newfoundland	50
Nova Scotia	56
New Brunswick and Cape Breton	59
Maine	68
New Hampshire	70
Eastern Massachusetts	72
Paleontology	78
Newfoundland	78
New Brunswick and Cape Breton	80
Eastern Massachusetts	88
Appalachian Province	91
Northern Appalachian district	91
Granular Quartz	91
Red Sandrock	96
Georgia slates	98
Potsdam Sandstone	113
Canadian extension	114
Southern Appalachian district	122
New Jersey	122
Delaware	123
Pennsylvania	124
Maryland	133
Virginia	133
North Carolina	138
Tennessee	139
Georgia	144
Alabama	146
Paleontology	148
Northern Appalachian district	148
Southern Appalachian district	154
New Jersey, etc	154
Tennessee	154
Georgia	155
Rocky Mountain Province	155
Utah and Nevada	155
Idaho	161

Page.

CHAPTER II—Continued.

Montana 162
Canadian extension 163
Paleontology 165
Interior Continental Province 171
Upper Mississippi area 171
Wisconsin 171
Minnesota 181
Iowa 187
Lake Superior sandstone 188
Missouri 199
Eastern border or Adirondack sub-Province 201
Canadian Extension 207
Western Border or Rocky Mountain sub-Province 209
Colorado 209
Wyoming 211
Dakota 214
Southwestern sub-Province 216
Texas 216
Arizona 219
Paleontology 221
Upper Mississippi area 221
Red sandstone of Lake Superior 228
Missouri 229
Eastern border or Adirondack sub-Province 229
Western border or Rocky Mountain sub-Province 233
Texas 234
Arizona 235
CHAPTER III. Nomenclature employed in the description of the formations 236
Cambrian 237
Taconic 242
Taconian 243
Primordial 243
Potsdam 244
St. Croix 245
Madison 245
Mendota 245
Tonto 245
Hamburg 246
Secret Cañon 246
Katemcy 246
Riley 246
Hickory 246
Connasauga 246
Montevallo 247
Choccolocco 247
Coosa 247
Rome sandstone 247
Bretonian 247
Acadian 248
St. John's 248
Johannian 249
Georgia 249
Granular Quartz 250

Page.

CHAPTER III—Continued.
Red Sandrock ... 250
Primal ... 251
Chilhowee ... 251
Weisner ... 251
Ocoee ... 252
Prospect ... 252
Eastern and Western sandstone ... 252
Lake Superior sandstone ... 252
Potsdamic ... 252
CHAPTER IV. Summary of the present knowledge of the formations ... 253
Atlantic Coast Province ... 253
Newfoundland and the adjoining coast of Labrador ... 253
Northwestern Newfoundland ... 253
Southwestern Newfoundland ... 256
Eastern and Southeastern Newfoundland ... 257
Nova Scotia ... 262
New Brunswick and Cape Breton ... 262
Maine ... 267
New Hampshire ... 267
Eastern Massachusetts ... 268
Résumé ... 273
Appalachian Province ... 274
Northern Appalachian district ... 275
Canadian extension ... 285
Southern Appalachian district ... 287
New Jersey ... 287
Delaware ... 288
Pennsylvania ... 288
Maryland ... 289
Virginia ... 290
North Carolina ... 299
Tennessee ... 299
Ocoee conglomerate ... 299
Chilhowee sandstone ... 300
Knox sandstone and shale ... 301
Georgia ... 303
Alabama ... 305
Résumé ... 308
Rocky Mountain Province ... 313
Utah and Nevada ... 313
Idaho ... 320
Montana ... 323
Canadian extension ... 326
Résumé ... 328
Interior Continental Province ... 330
Upper Mississippi Valley ... 330
Canadian extension ... 334
Lake Superior sandstone ... 335
Canadian extension ... 339
Missouri ... 339
Eastern border or Adirondack sub-Province and its Canadian extension ... 341
Section at Potsdam ... 342
Section at Chateaugay Chasm ... 342

Page.

CHAPTER IV—Continued.
Section at Hemmingford 343
Section at Keeseville and in Au Sable Chasm 343
Section at Whitehall 344
Section at Saratoga 346
Western border or Rocky Mountain sub-Province 347
South Dakota 347
Wyoming 349
Colorado 351
Southwestern sub-Province 354
Texas 354
Arizona 356
Résumé 357
Synopsis of the Cambrian group 359
Base of Cambrian 362
Summit of Cambrian 362
Sedimentation of the Cambrian group 363
Subdivision of the Cambrian 370
Comparison with the Cambrian rocks of other countries 373
Europe 373
Scotland 376
Ireland 377
China 377
India 378
Australia 378
South America 379
CHAPTER V. Problems for investigation and settlement 380
Local problems 380
Newfoundland 380
Nova Scotia 380
New Brunswick 381
Maine and New Hampshire 381
Eastern Massachusetts 381
New York 381
Adirondack sub-Province 381
Vermont 381
Canadian extension 382
New Jersey 382
Pennsylvania 382
Virginia 383
North Carolina 383
Tennessee 383
Georgia and Alabama 383
Utah and Nevada 384
Colorado 384
Rocky Mountains 384
Arizona 385
Upper Mississippi Valley 385
Missouri 385
Texas 385
Problems affecting our knowledge of the Cambrian group as a whole or in large parts 385
Problems of nomenclature and classification 388
The name 388
The limit of the group 388

Page.

CHAPTER VI.—The criteria and principles used by authors in the correlation of the various parts composing the group, with observations on some methods of correlation 391
Historical notes 391
America 391
Maclure 391
Eaton 392
Bigsby 395
James 396
Bakewell 397
De la Beche 398
Eaton 399
Conrad 399
Hall 401
Emmons 403
Rogers 403
Safford 405
Canada 405
Logan 405
Newfoundland 406
Dana 407
Mississippi Valley 408
Hall 408
Winchell 409
Meek 410
Rocky Mountains 411
Whitney 411
Bradley 411
Fortieth Parallel Survey 412
Explorations and Surveys West of One Hundredth Meridian 412
Geological Surveys of the Territories 412
U. S. Geological Survey 413
Correlations with European formations 414
De Verneuil 414
Hall 415
Barrande 416
Rogers 417
Bigsby 418
Agassiz 419
Matthew 420
Methods of correlation 421
Superposition 421
Organic remains 422
Life zones 424
Stage of evolution 425
Life history 426
Contemporaneity and homotaxis 427
Percentage of species 428
Lithologic character 428
Unconformity 429
Miscellaneous 432
Homogeny 432
Topographic features 434

ILLUSTRATIONS.

Page.

PLATE I. Map showing the distribution, by geologic provinces, of the Cambrian strata as shown by surface outcrops in North America..... 358

II. Map to illustrate geologic provinces and relative thickness of the Cambrian rocks of North America, with theoretic sections of the Cambrian group at the close of Cambrian time..... 365

III. Hypothetical map of the North American continent at the beginning of and during Lower Cambrian time..... 368

FIG. 1. Typical sections of the Atlantic Coast Province..... 274

2. Typical sections of the Appalachian Province..... 311

3. Typical sections of the Rocky Mountain Province..... 329

4. Typical sections of the Interior Continental Province..... 357

5. Typical sections of the Interior Continental Province..... 358

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF GEOLOGIC CORRELATION,
Washington, D. C., April 1, 1891.

SIR: I have the honor to transmit herewith a memoir by Mr. C. D. Walcott, on the Cambrian of North America, prepared for publication as a bulletin.

The Division of Geologic Correlation was created for the purpose of summarizing existing knowledge with reference to the geologic formations of North America, and especially of the United States; of discussing the correlation of the formations found in different parts of the country with one another, and with formations in other continents; and of discussing the principles of geologic correlation in the light of American phenomena. The formations of each geologic period were assigned to some student already well acquainted with them and it was arranged that he should expand his knowledge by study of the literature, and by field examination of classic localities, and embody his results in an essay. The general plan of the work has been set forth on page 16 of the Ninth Annual Report of the Survey, and on pages 108 to 113 of the Tenth Annual Report, as well as in a letter of transmittal to Bulletin No. 80 of the Survey.

The first of the series of essays resulting from this work, prepared by Prof. Henry S. Williams, pertains to the formations of the Carboniferous and Devonian periods, and constitutes Bulletin No. 80. The present essay is the second of the series, and others will follow.

Mr. Walcott finds that the American Cambrian includes three faunas, of which the first and third are of continental range, and that by the aid of these faunas the formations in the various geologic provinces may be classified into three divisions, an upper, a middle, and a lower. He finds also that these divisions may be homotaxially, and perhaps chronologically, compared with divisions of the European Cambrian.

Very respectfully, your obedient servant,

G. K. GILBERT,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

OUTLINE OF THIS PAPER.

This work is a review, by one who is working in the Cambrian field, of the work of his predecessors, and of the results they and he have thus far obtained as he interprets them. It thus becomes historical and descriptive, and is a general statement of the principles upon which the correlations have been made in establishing the group.

Chapter I gives a statement of the principles upon which the delimitation of the group is based, a few brief remarks upon the nomenclature of the formations, and a list of the books and articles consulted in the preparation of this paper.

Chapter II gives a historical review of the geologic and paleontologic work that has been done in the four provinces in which the sediments of the Cambrian group occur. These are the Atlantic Coast Province; the Appalachian Province, which is divided into the Northern Appalachian and Southern Appalachian areas; the Rocky Mountain Province, and the Interior Continental Province. The latter is divided into the Upper Mississippi Area, the Eastern Border or Adirondack sub-Province, the Western Border or Rocky Mountain sub-Province, and the Southwestern sub-Province of Texas and Arizona. Within each of the provinces the historical data are reviewed by the political divisions of States and Territories, and in British North America by provinces.

The historical review of the geologic work embraces all that has come within the knowledge of the writer of the descriptive geology of the rocks now referred to the Cambrian group. The paleontologic review includes only the mention of the genera and species described by the various authors.

Chapter III is a record of the names that have been employed to designate various formations. It is of an historical rather than a controversial character.

Chapter IV gives a summary of the present knowledge of the formations in each of the four geologic provinces, in the same arrangement as that of the historical review in chapter II. The attempt is made to give a concise statement of the present knowledge of the formations referred to the Cambrian group within each province. The paleontologic references are to the larger subdivisions of the fauna without mention of genera or species. These will be described in special monographs, now in the course of preparation. At the close of this summary there is a synopsis of the Cambrian group, in which it is stated that the group is established by (*a*) the presence in the Rocky Mountain Province of 6,000 feet of limestone with an undetermined mass of quartzite beneath; (*b*) in the Appalachian Province by over 12,000 feet of quartzite, shales, slates, and limestones; (*c*) a continental distribution; (*d*) a characteristic, highly differentiated fauna. A table of the classification of the formations is arranged with the type formation of each subdivision at the head, while beneath are the formations correlated with it.

A map showing the geographic distribution accompanies this chapter; also one on which the sedimentation is illustrated by vertical columns of strata. A section across the continent, with the base of the Ordovician fauna as the upper limit and the columns of strata arranged beneath it, reveals the presence of a great trough along the line of the Appalachians from Alabama to Labrador, and a second trough on the western side of the continent west of the eastern Rocky Mountain ranges. It is claimed that the great interior Continental Province was a land area during

Lower and Middle Cambrian time and that the Cambrian Sea did not enter upon it until the beginning of Upper Cambrian time. A map based (Pl. III) upon this view illustrates the supposed land area at the beginning of Cambrian time.

The base of the group is stated to be where the oldest known fauna that is referred to the Cambrian fauna occurs. The summit of the group is the transition from the Cambrian to the Ordovician fauna, or in the New York section between the Potsdam sandstone and the superjacent Calciferous formation. The rocks or sediments are described and the conclusion reached that there were geographic areas in which different types of sedimentation prevailed, and that as a whole the sediments were deposited in both shallow and deep waters on an ocean bottom that was being slowly depressed in relation to sea level.

The study of the fauna indicates that the group may be conveniently divided into three divisions, lower, middle, and upper. The evidence of the sedimentation and organic remains proves the presence of geographic provinces in Lower Cambrian time that became more strongly differentiated in Middle Cambrian time and less strongly marked in Upper Cambrian time.

The chapter concludes by notes on the Cambrian rocks of Great Britain, Europe, China, India, Australia, and South America.

Chapter V deals with problems for investigation and settlement which are taken up, for the local problems, in the same order of presentation as the matter in chapters II and IV. The general problems respecting our knowledge of the Cambrian group, as a whole, or in large parts, are discussed separately, as are the problems of nomenclature and classification. The latter includes a statement of the problems relating to the name and the limits of the group.

Chapter VI is devoted to the study of criteria and principles used by authors in the correlation of the various parts composing the Cambrian group, with observations on some methods of correlation. The first portion includes the historical notes, and is a review in chronologic order of the principles of correlation used by authors in the United States and Canada, and observations by authors upon correlation of American with European formations. This review shows that many authors have expressed sound views upon methods of correlation and that, with the exception of the additions made since the theory of evolution began to influence paleontologists, the addition to methods has been relatively small. Under the heading of methods of correlation, correlation by superposition, organic remains, lithologic characters, and unconformity are treated of at some length. Under organic remains are considered life zones, stage of evolution, life history, contemporaneity, homotaxis, and percentage of species. Reference is also made to homogeny and topographic features as elements entering into the problems of correlation.

THE CAMBRIAN GROUP OF ROCKS IN NORTH AMERICA.

By Charles D. Walcott.

CHAPTER I.

INTRODUCTORY.

This report is an unfinished memoir. It is an account of the present knowledge of a great geologic group that will require prolonged investigation to bring it to the status in descriptive geology already attained by the superjacent members of the Paleozoic system.[1]

The history of the origin and application of the term Cambrian in geologic nomenclature is presented in connection with the description of the names that have been employed in the classification of the various formations characterized by the types of the "First or Primordial Fauna" of Barrande. The basal fauna, as now known, is that of the Olenellus zone; and the upper horizon of the group is drawn at the summit of the series characterized by the Dikellocephalus fauna of North America. The delimitation of the group is based on the principles: (*a*) that the great geologic groups must rest on the broad zoologic characters of their included faunas, and not upon local stratigraphic breaks between certain series of rocks or upon local differences in sedimentation; (*b*) that the most reliable chronologic scale in geology is that afforded by the relative magnitude of zoologic change; and (*c*) that the geologic duration and importance of any system are in strict proportion to the comparative magnitude and distinctness of its collective fauna.[2]

Geologic classification has been largely based upon the imperfections of the geologic record and an arbitrary assumption of breaks in the chain of sedimentation and life that are not of universal extent. Geologic continuity must have been a fact and the sequence of life and deposition continued uninterrupted on some portion of the earth from the earliest Cambrian time to the present day. Such continuity could not have existed in any one province, and it is doubtful if the complete record will ever be regained. In its absence the classification already

[1] In the preparation of the historical portion I received material assistance from Prof. Joseph F. James, who, taking as a basis the bibliographic card-catalogue of Mr. N. H. Darton, prepared a series of brief abstracts which guided me in my historical research.

[2] Lapworth, Charles. Geological Magazine, new ser., dec. II, 1879, vol. 6, p. 3.

established is adopted and then arbitrarily assumed whenever the original basis for it is cleared away by more perfect knowledge.

For convenience of description and geologic cartography, the geologic formation[1] is taken as the primary unit of classification. The combination of these primary units forms the terrane, which may be composed of any number of geologic units. The groupings of the terranes form the groups, and the union of the groups the systems. Thus the Potsdam sandstone of the Adirondacks, the Dutchess County limestone of New York, the upper Knox shales of Tennessee, the Hamburg shales of Nevada, and many other formations unite to form the Upper Cambrian terrane. The union of the Upper Cambrian with the Middle and the Lower Cambrian builds up the Cambrian group. The combination of the Cambrian, Silurian, Devonian, and Carboniferous, forms the Paleozoic system.

The nomenclature of the formations of any group frequently expresses in local terminology the history of the development or evolution of knowledge of the group. For instance, the formations composing the Cambrian begin, in America, with the "Granular Quartz" and then follow the Potsdam sandstone, the St. John shales, the Chilhowee sandstone, etc. The plan of naming the formations from the locality at which they are best developed is a great safeguard and can be frequently adopted. For instance, the Potsdam sandstone of New York has its type locality at Potsdam in St. Lawrence County, where it can be readily identified. To say it is identical with the Upper Cambrian or St. Croix sandstone of the Mississippi Valley, with which it has been identified, and to speak of the latter as the Potsdam sandstone, is to practically state that they are synchronous. The use of the name St. Croix does not imply this. It enables the geologist to mention the formation without assuming a correlation that he may or may not believe in.

[1] Dr. J. J. Bigsby states that "According to Deshayes 'a formation is a space of time represented by a certain number of beds, laid down under the influence of the same phenomena,' or, in other words, a formation is characterized by the constancy of its fossils." (On the Paleozoic basin of the State of New York. Part II. Classification of the Paleozoic strata of the State of New York. Quart. Jour. Geol. Soc. London, 1858, vol. 14, pp. 428, 430.)

LITERATURE.

LIST OF AUTHORS AND YEAR OF PUBLICATION.

Adams (C. B.), 1845, 1846, 1847, 1848.
Agassiz (Alexander), 1868.
Agassiz (Louis), 1862.
Ami (H.) and Sowter (T. W. E.), 1887.
Aveline (W.T.); Salter (J.W.), and, 1853.
Bailey (L. W.), 1865, 1879.
Bailey (L. W.) and Matthew (G. F.), 1872.
Bailey (L. W.); Matthew (G. F.), and, 1869.
Bailey (L. W.), Matthew (G. F.), and Ells (R. W.), 1880.
Baily (W. H.), 1865.
Bakewell (Robert), 1829.
Barrande (J.), 1846, 1852, 1853, 1860, 1861.
Barrande (Joachim), and Marcou (Jules), 1860.
Bayfield (H. W.), 1829, 1845.
Beecher (C. E.) and Hall (C. E.), 1886.
Bell (Robert), 1879.
Bergeron (Jules), 1888.
Bigsby (John J.), 1824, 1825, 1827, 1853, 1858, 1863.
Billings (E.), 1860, 1861, 1862, 1865, 1872.
Bradley (Frank H.), 1860, 1872, 1873, 1874, 1875.
Broadhead (G. C.), 1874, 1877, 1882, 1889.
Brögger (W. C.), 1886.
Brooks (T. B.), and Pumpelly (R.), 1872.
Buckley (S. B.), 1874, 1876.
Burt (William A.), 1849.
Calvin (S.), 1888.
Campbell (H. D.), 1885.
Campbell (J.), 1863.
Campbell (J. L.), 1879, 1880, 1884.
Campbell (J. L. and H. D.), 1884, 1885.
Campbell (J. L.) and Ruffner (W. H.), 1883.
Carpenter (F. R.), 1888.
Chamberlin (T. C.), 1877, 1883.
Chamberlin (T. C.); Irving (R. D.), and, 1885.
Chapman (E. J.), 1877.
Chester (Frederick D.), 1884.
Clemson (Thomas G.), 1835.
Comstock (T. B.), 1874, 1890.
Conrad (T. A.), 1839, 1840, 1841, 1842.
Cook (George H.), 1863, 1868, 1874, 1884, 1885.
Crosby (W. O.), 1876, 1880, 1881, 1889.
Dames (Wilhelm), 1883.
Dana (Edw. S.) and Grinnell (G. B.), 1876.
Dana (James D.), 1863, 1872, 1874, 1877, 1885, 1887, 1890.
Dana (J. F. and S. L.), 1818.
Daniels (Edward), 1859.
Dawson (George M.), 1884, 1886, 1887.
Dawson (J. W.), 1850, 1855, 1860, 1862, 1867, 1868, 1873, 1878, 1883, 1888.
D'Invilliers (E.), 1883.
De la Beche (Henry), 1832.
Desor (E.), 1851.
Devine (T.), 1863.
Dewey (Chester), 1819, 1820, 1824.
Dodge (W. W.), 1875.
Dutton (Clarence E.), 1881.
Dwight (William B.), 1886, 1887, 1889.
Eaton (Amos), 1818, 1820, 1822, 1824, 1828, 1830, 1832, 1839.
Elliott (John B.), 1883.
Ells (R. W.), 1887, 1889.
Ells (R. W.); Bailey (L. W.), Matthew (G. F.), and, 1880.
Emmons (Ebenezer), 1837, 1838, 1839, 1840, 1841, 1842, 1844, 1847, 1856.
Emmons (S. F.), 1886.
Emmons (S. F.); Hague (Arnold), and 1877.
Endlich (F. M.), 1878, 1879.
Engelmann (H.), 1857.
Etheridge (R., jr.), 1883, 1890.
Ferrier (W. F.), 1883.
Fitch (Asa), 1850.
Fletcher (Hugh), 1877, 1878.
Foerste (A. F.); Shaler (N. S.), and, 1888.
Foerste (Aug. F.), 1889.
Fontaine (William M.), 1875, 1883.

Ford (S. W.), 1871, 1872, 1873, 1875, 1876, 1877, 1878, 1880, 1881, 1884, 1886.
Foster (J. W.), 18 49.
Foster (J. W.) and Whitney (J. D.), 1849, 1850, 1851.
Frazer (Persifor, jr.), 1878, 1879, 1880, 1882, 1883, 1886.
Geiger (H. R.) and Keith (Arthur), 1891.
Geikie (Archibald), 1882.
Gesner (Abraham), 1836, 1841, 1843, 1845, 1849.
Gilbert (G. K.), 1874, 1875, 1890.
Grinnell (G. B.); Dana (Ewd. S.), and, 1876.
Green (Jacob), 1834.
Hague (Arnold) 1881, 1882.
Hague (Arnold) and Emmons (S. F.), 1877.
Hall (Charles E.), 1881, 1885. (See Beecher, C. E.)
Hall (James) 1839, 1843, 1844, 1845, 1847, 1851, 1858, 1859, 1860, 1861, 1862, 1863, 1873, 1884, 1886.
Hall (James) and Whitfield (R. P.), 1873, 1877.
Hall (James); Logan (W. E.), and, 1866.
Hartt (C. Fred.), 1865, 1868.
Harvey (M.); Hatton (Joseph), and, 1883.
Hatton (Joseph) and Harvey (M.), 1883.
Hayden (F. V.), 1858, 1859, 1861, 1862, 1863, 1869, 1871, 1873, 1874, 1875, 1885, 1888.
Henderson (J. T.), 1885.
Hicks (Henry), 1875.
Hind (H. Y.), 1869, 1870.
Hitchcock (C. H.), 1861, 1862, 1867, 1870, 1873, 1874, 1875, 1877, 1879, 1884, 1885, 1888, 1890.
Hitchcock (Edw.), 1832, 1841, 1859.
Hough (Franklin B.), 1847, 1850, 1851.
Houghton (Douglass), 1839, 1840, 1841.
Howell (Edwin E.), 1875.
Hubbard (Bela), 1849.
Hunt (T. S.), 1852, 1854, 1861, 1868, 1870, 1871, 1875, 1876, 1878, 1879, 1883, 1886.
Hyatt (Alpheus), 1885.
Irving (Roland D.), 1872, 1874, 1875, 1877, 1880, 1883, 1885, 1888.
Irving (R. D.) and Chamberlin (T. C.), 1885.
Jackson (C. T.), 1844, 1849, 1851, 1856, 1859, 1861.
James (Edwin), 1821, 1822.
Jenney (W. P.), 1874.
Johnston (J. F. W.), 1850.
Jukes (J. Beete), 1843, 1862.
Kayser (Emanuel), 1876.
Kerr (W. C.), 1869, 1875.
Killebrew (J. B.), 1874.
King (Clarence), 1876, 1878.
King (H.), 1851.
King (William), 1689.
Kloos (J. H.), 1882.
Lane (Alfred C.), 1889.
Lapham (I. A.), 1851, 1855, 1869.
Lapworth (Charles), 1881.
Lea (Isaac), 1858.
Lesley (J. P.), 1853, 1873, 1883, 1885.
Lewis (H. Carvill), 1883.
Little (George), 1876.
Lloyd (T. G. B.), 1876.
Logan (W. E.), 1845, 1847, 1849, 1850, 1851, 1852, 1854, 1855, 1860, 1861, 1863, 1865, 1866.
Logan (W. E.) and Hall (James), 1866.
Low (A. P.), 1884, 1886.
Lydekker (R.); Nicholson (H. A.), and, 1889.
Lyell (Charles), 1845.
Lyman (B. S.), 1867.
McConnell (R. G.), 1887, 1889.
McCreath (Andrew), 1884.
McCutchen (A. R.), 1884.
McGee (W J), 1890.
Macfarlane (Thomas), 1867.
Maclure (William), 1809, 1817.
Marcou (Jules), 1850, 1861, 1862, 1880, 1885, 1888.
Marcou (Jules); Barrande (Joachim) and, 1860.
Marr (J. E.), 1880, 1883.
Marsh (O. C.), 1869.
Marvine (A. R.), 1875.
Mather (William W.), 1841, 1843.
Matthew (G. F.), 1863, 1865, 1878, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890, 1891.
Matthew (G. F.) and Bailey (L. W.), 1869.
Matthew (G. F.); Bailey (L. W.), and, 1872.
Matthew (G. F), and Ells (R. W.); Bailey (L. W.), and, 1880.
Meads (A. D.), 1889.
Meek (F. B.), 1868, 1870, 1871, 1872, 1873, 1877.
Meek (F. B.) and Hayden (F. V.), 1858, 1859, 1861, 1864.
Milne (John) and Murray (Alexander), 1877.
Murchison (R. I.); Sedgwick (Adam), and, 1835.

Murray (Alexander); Milne (John), and, 1877.
Murray (Alexander), 1852, 1854, 1866, 1868, 1870, 1871, 1873, 1881.
Nason (Frank L.), 1891.
Newberry (J. S.), 1861, 1873, 1874.
Newton (Henry), 1880.
Nicholson (H. A.) and Lydekker (R.), 1889.
Norwood (J. C.), 1852.
Ordway (Albert), 1861.
Owen (David Dale), 1843, 1848, 1851, 1852.
Owen (Richard), 1852, 1862.
Peale (A. C.), 1874, 1876, 1879, 1890.
Percival (James G.), 1856.
Perkins (George H.), 1885.
Perry (John P.), 1867, 1868.
Powell (J. W.), 1875, 1876.
Prime (Frederick, jr.), 1878, 1883.
Prout (H. A.), 1851.
Pumpelly (R.); Brooks (T. B.), and, 1872.
Rafinesque (C. S.), 1818.
Rand (T. D.), 1889.
Richardson (James), 1870.
Richthofen (F. F. von), 1882.
Robb (James), 1850.
Roemer (Ferdinand), 1849, 1852.
Rogers (Henry D.), 1838, 1839, 1840, 1841, 1844, 1846, 1857, 1858.
Rogers (Henry D. and W. B.), 1842.
Rogers (William B.), 1838, 1839, 1844, 1856, 1861, 1875, 1879, 1884.
Rominger (C.), 1873, 1887.
Ruffner (W. H.); Campbell (J. L.), and 1883.
St. John (Orestes), 1879, 1883.
Safford (J. M.), 1856, 1869, 1879.
Salter (J. W.), 1859.
Salter (J. W.) and Aveline (W. T.), 1853.
Schoolcraft (H. R.), 1855.
Sears (John H.), 1890.
Sedgwick (Adam), 1838, 1852, 1873.
Sedgwick (Adam) and Murchison (R. I.), 1835.
Selwyn (A. R. C.), 1872, 1879, 1883.
Shaler (N. S.), 1869, 1888, 1889.
Shaler (N. S.) and Foerste (A. F.), 1888.
Shaler (N. S.) and Williams (H. S.), 1891.
Shumard (B. F.), 1852, 1859, 1861, 1862.
Smith (E. A.), 1875, 1876, 1878, 1883, 1884.
Smock (John C.), 1886.
Sowter (T. W. E.); Ami (H.), and, 1887.
Steele (John H.), 1823, 1825.
Stevenson (John J.), 1887.
Strong (Moses), 1877, 1880, 1882.
Swallow (G. C.), 1855, 1871.
Sweet (E. T.), 1876, 1880.
Thompson (Zadock), 1853.
Todd (James E.), 1882.
Troost (Gerard), 1838, 1840, 1841.
Tuomey (M.), 1858.
Tyson (Philip T.), 1860.
Upham (Warren), 1884, 1885, 1888.
Vanuxem (Lardner), 1840, 1842.
Verneuil (Ed. de), 1847.
Wadsworth (M. E.), 1880, 1882, 1884.
Wadsworth (M. E.); Whitney (J. D.), and, 1884.
Walcott (Charles D.), 1879, 1880, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890.
Webster (J. W.), 1824.
White (C. A.), 1870, 1874, 1875, 1876, 1879, 1880.
White (George), 1849.
Whiteaves (J. F.), 1878.
Whitfield (R. P.), 1876, 1877, 1878, 1880, 1882, 1884.
Whitfield (R. P.); Hall (James), and, 1873, 1877.
Whitney (J. D.), 1855, 1858, 1862, 1872, 1883.
Whitney (J. D.) and Wadsworth (M. E.), 1884.
Whitney (J. D.); Foster (J. W.), and, 1849, 1850, 1851.
Whittlesey (Charles), 1851, 1863.
Williams (H. S.), 1888.
Winchell (Alexander), 1861, 1864.
Winchell (N. H.), 1873, 1874, 1876, 1878, 1880, 1882, 1883, 1884, 1885, 1886, 1888, 1889.
Winchell (N. H., and H. V.), 1890.
Winwood (H. H.), 1885.
Wolff (J. E.), 1891.
Woodward (Henry), 1884.
Woodward (J.), 1723.
Wooster (L. C.), 1878, 1882, 1884.
Young (A. A.), 1882.

LIST OF PAPERS BY DATES.

1723.

WOODWARD, Dr. J. An essay toward a Natural History of the Earth and Terrestrial Bodies. London, 3d edition, 1723.

1809.

MACLURE, WILLIAM. Observations on the Geology of the United States Explanatory of a Geological Map. Am. Phil. Soc. Trans., vol. 6, 1809, pp. 411–428, map.

1817.

MACLURE, WILLIAM. Observations on the Geology of the United States; with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils. With a map and two plates. Am. Phil. Soc. Trans., new series, vol. 1, 1817, pp. 1–91.

1818.

DANA, J. F., and S. L. DANA. Outlines of the Mineralogy and Geology of Boston and its vicinity, with a geological map. Am. Acad. Arts and Sciences, Memoirs, vol. 4, 1818, pp. 129–223.

EATON, AMOS. An Index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 52.

R(AFINESQUE) C. S. Observations on the Geology of the United States of America, by William Maclure; a notice. Am. Monthly Magazine, vol. 3, 1818, pp. 41–44.

1819.

DEWEY, CHESTER. Sketch of the Mineralogy and Geology of the Vicinity of Williams' College, Williamstown, Mass. (With a map.) Am. Jour. Sci., vol. 1, 1819, pp. 337–346.

1820.

DEWEY, CHESTER. Geological section from Taconick Range, in Williamstown, to the city of Troy, on the Hudson. Am. Jour. Sci., vol. 2, 1820, pp. 246–248.

EATON, AMOS. An Index to the Geology of the Northern States. 2d Ed., Troy, N. Y., 1820, pp. 286.

1821.

JAMES, EDWIN. Remarks on the sandstone and floetz formations of the western part of the valley of the Mississippi. Am. Phil. Soc. Trans., new series, vol. 2, 1821, pp. 191–215.

1822.

EATON, AMOS. A geological and agricultural survey of Rensselaer County, New York, with a geological profile, from Onondaga to Massachusetts. Albany, 1822, pp. 70, plate. Memoirs of the Board of Agriculture of the State of New York, 1823, vol. 2, pp. 3–43.

JAMES, EDWIN. Geological sketches of the Mississippi Valley. Phila. Acad. Sci., Jour., vol. 2, 1822, pp. 326–329.

1823.

STEELE, JOHN H. A report of the geological structure of the county of Saratoga. Memoirs of the Board of Agriculture of the State of New York, vol. 2, 1823, pp. 44–84, 155–161.

1824.

BIGSBY, JOHN J. A list of mineral and organic remains occurring in the Canadas. Am. Jour. Sci., vol. 8, 1824, pp. 60–88.

DEWEY, CHESTER. A sketch of the geology and mineralogy of the western part of Massachusetts, and a small part of the adjoining States. Am. Jour. Sci., vol. 8, 1824, pp. 1–60.

EATON, AMOS. A geological and agricultural survey of the district adjoining the Erie Canal. Albany, 1824, pp. 163, plate.

WEBSTER, J. W. Remarks on the geology of Boston and its vicinity. Boston Jour. Phil. and Arts, vol. 2, 1824, pp. 277–292.

1825.

BIGSBY, J. J. Notes on the geography and geology of Lake Superior. Quar. Jour. Lit., Sci. and Arts (of the Royal Inst. of Gt. Britain,) vol. 18, 1825, pp. 1–34, 228–269, map.

STEELE, JOHN H. A description of the Oolitic Formation lately discovered in the county of Saratoga, and State of New York. Am. Jour. Sci., vol. 9, 1825, pp. 16–19.

1827.

BIGSBY, J. J. On the geology of Quebec and its vicinity. Geol. Soc. London, Proc., vol. 1. 1827, pp. 37, 38.

1828.

EATON, AMOS. Geological nomenclature, exhibited in a synopsis of North American rocks and detritus. Am. Jour. Sci., vol. 14, 1828, oppo. p. 144, pp. 145–159; 359–368.

——— Annunciation of the second part of Prof. A. Eaton's report of the geological survey on the Erie Canal. Am. Jour. Sci., vol. 13, 1828, pp. 383–385.

1829.

BAKEWELL, ROBERT. Introduction to Geology, 1st American Edition, New Haven, 1829.

BAYFIELD, H. W. Outlines of the geology of Lake Superior. Quebec Lit. and Hist. Soc. Trans., vol. 1, 1829, pp. 1–43.

1830.

EATON, AMOS. Geological text-book, prepared for popular lectures on North American geology; with applications to agriculture and the arts. Albany, 1830, pp. 64, pls. and map.

1832.

DE LA BECHE, HENRY. Geological Manual, Philadelphia, 1832.

EATON, AMOS. Geological text-book for aiding the study of North American Geology; being a systematic arrangement of facts collected by the author and his pupils under the patronage of the Hon. Stephen Van Rensselaer. Second edition. 5 plates. Albany, 1832.

——— Geological equivalents. Am. Jour. Sci., vol. 21, 1832, pp. 132–138.

——— Four cardinal points in stratigraphical geology established by organic remains Am. Jour. Sci., vol. 21, 1832, pp. 199–200.

HITCHCOCK, EDW. Report on the geology of Massachusetts; examined under the direction of the government of that State during the years 1830 and 1831. Am. Jour. Sci., vol. 22, 1832, pp. 1–70, with map.

1834.

GREEN, JACOB. Descriptions of some new North American trilobites. Am. Jour. Sci., vol. 25, 1834, pp. 334–337.

1835.

CLEMSON, THOMAS G. Notice of a geological examination of the country between Fredericksburg and Winchester, in Virginia, including the gold region. Geol. Soc. Pennsylvania, Trans., vol. 1, 1835, pp. 298–313. (Colored map of sections.)

SEDGWICK, ADAM, and R. I. MURCHISON. On the Silurian and Cambrian systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales. Brit. Assoc. Report for 1835, part 2, pp. 59–61.

1836.

GESNER, ABRAHAM. Remarks on the geology and mineralogy of Nova Scotia. Halifax, N. S., 1836, pp. 272.

1837.

EMMONS, EBENEZER. First annual report of the second geological district of New York. First annual report of the geological survey of New York, Albany, 1837, pp. 97–150; map.

1838.

EMMONS, EBENEZER. Report of the geologist of the second geological district of New York. Second annual report of the geological survey of New York, Albany, 1838, pp. 185–250; pl. 4, map.

ROGERS, HENRY D. Second annual report on the geological exploration of the State of Pennsylvania. Harrisburg, 1838, pp. 93, plate.

ROGERS, WILLIAM B. Second report of the progress of the geological survey of the State of Virginia, for the year 1837. Richmond, 1838, pp. 24. (This report occupies pp. 147–188 in the reprint "Geology of the Virginias," New York, 1884.)

SEDGWICK, ADAM. A synopsis of the English series of stratified rocks inferior to the old red Sandstone, with an attempt to determine the successive natural groups and formations. Geol. Soc. London, Proc. vol. 2, 1838, pp. 675–685 (read May 23, 1838).

TROOST, GERARD. Fourth report of the geologist of the State of Tennessee. Nashville, 1838. Map, pp. 628–652.

1839.

CONRAD, T. A. Notes on American Geology. Am. Jour. Sci., vol. 35, 1839, pp. 237–251.

——— Second annual report on the paleontological department of the survey. Third annual report of the geolo. ical survey of New York, Albany, 1839, pp. 57–66.

EATON, AMOS. Cherty Limerock, or Corniferous Limerock, proposed as the line of reference for State geologists of New York and Pennsylvania. Am. Jour. Sci., vol. 36, 1839, pp. 61–71, 198.

EMMONS, EBENEZER. Third annual report of the second geological district. Third annual report of the geological survey of New York, Albany, 1839, pp. 201–239.

HALL JAMES. Third annual report of the fourth geological district of New York. Third annual report of the geological survey of New York, Albany, 1839, pp. 287–339.

HOUGHTON, DOUGLASS. [Peninsula District.] Second annual report State geologist of Michigan, Detroit, 1839, pp. 4–39.

ROGERS, HENRY D. Third annual report on the geological survey of the State of Pennsylvania. Harrisburg, 1839, pp. 119.

ROGERS, WILLIAM B. Report of the progress of the geological survey of Virginia, for 1838 (Richmond, 1839), pp. 32. (This report occupies pp. 189–244 of the reprint "Geology of the Virginias," New York, 1884.)

1840.

CONRAD, T. A. On the Silurian system, with a table of the strata and characteristic fossils. Am. Jour. Sci., vol. 38, 1840, pp. 86–93.
EMMONS, EBENEZER. Fourth annual report of the survey of the second geological district of New York. Fourth annual report of the geological survey of New York, Albany, 1840, pp. 259–353.
HOUGHTON, DOUGLASS. Third Ann. Rep. State Geol. of Michigan. House Reps. Document No. 8. 1840, pp. 33.
ROGERS, HENRY D. Description of the geology of the State of New Jersey, being a final report. Philadelphia, 1840, with plate and map. pp. 301.
——— Fourth annual report on the geological survey of the State of Pennsylvania. Harrisburg, 1840, pp. 252.
TROOST, GERARD. Fifth geological report on the State of Tennessee. Nashville, 1840, pp. 44, 3 maps.
VANUXEM, LARDNER. Fourth annual report of the geological survey of the third district. Fourth report of the geological survey of New York, Albany, 1840, pp. 355–383.

1841.

CONRAD, T. A. Fifth annual report on the paleontology of New York. Fifth annual report of the geological survey of New York, Albany, 1841, pp. 25–57.
EMMONS, EBENEZER. Geology of the Montmorenci. American Magazine, vol. 1, 1841, pp. 146–150.
GESNER, ABRAHAM. Third report on the geological survey of the Province of New Brunswick. St. John, 1841, pp. 88.
HITCHCOCK, EDWARD. Final report on the geology of Massachusetts, 2 vols., Amherst, 1841, vol. 1, pp. XII, 299; vol. 2, pp. 300–831; 55 pls.
HOUGHTON, DOUGLASS. Report [on the Northern or Upper Peninsula]. Geol. Survey Michigan, 4th Ann. Rep. State geologist, 1841, pp. 4–89.
MATHER, W. W. Fifth annual report on the geological survey of the first geological district. Fifth annual report of the geological survey of New York, Albany, 1841, pp. 63–112.
ROGERS, H. D. Some observations on the geological structure of Berkshire, Massachusetts, and neighboring parts of New York. Am. Phil. Soc., Proc., vol. 2, 1841, pp. 3, 4.
——— Fifth annual report on the geological exploration of Pennsylvania. Harrisburg, 1841, pp. 156 and plate.
TROOST, GERARD. Sixth annual report of the geological survey of Tennessee by the State geologist. Nashville, 1841, pp. 48.

1842.

CONRAD, T. A. Observations on the Silurian and Devonian systems of the United States, with descriptions of new organic remains. Phila. Acad. Sci., Jour., vol. 8, 1842, pp. 228–235.
EMMONS, EBENEZER. Geology of New York, part 2, comprising the survey of the second geological (northern) district, 1842, pp. 438, pls. 17.
——— Topography, geology, and mineral resources of the State of New York. Gazetteer of the State of New York, by J. Disturnell, Albany, 1842, pp. 5–25.
ROGERS, H. D., and W. B. ROGERS. On the physical structure of the Appalachian Chain, as exemplifying the laws which have regulated the elevation of great mountain chains generally. Brit. Assoc. Rept., vol. 12, Trans. Sec., pp. 40–42; Am. Jour. Sci., vol. 44, 1842, pp. 359–362; Trans. Am. Assoc. Geol. and Nat., 1843, pp. 474–531.
VANUXEM, LARDNER. Geology of New York. Geology of the Third (central) Geological District. Albany, 1842, pp. 307.

1843.

GESNER, ABRAHAM. Report on the Geological Survey of the Province of New Brunswick, with a Topographical Account of the Public Lands and Districts Explored in 1842. St. John, 1843, pp. 88.
——— Memoir of the Geology of Nova Scotia, with a map. Geol. Soc. London, Proc., Vol. 4, 1843, pp. 186–190.
HALL, JAMES. Geology of New York. Geology of the Fourth (western) Geological District. Albany, 1843, pp. XXVII, 686, 19 pls. and map.

HALL, JAMES. Geological map of the Middle and Western States. Geol. of New York. Rep. on the Fourth Geological District, Albany, 1843.

——— Notes Explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a Southwest Direction; with remarks upón the Identity of the Western Formations with those of New York. Assoc. Am. Geol. Trans., 1843, pp. 267–293.

JUKES, J. B. General report of the Geological Survey of Newfoundland in 1839 and 1840, London, 1843, pp. 160, 2 pls.

MATHER, WILLIAM W. Geology of New York; Geology of the First (southeastern) District. Albany, 1843, pp. xxxvii, 655, 46 pls.

OWEN, DAVID DALE. On the Geology of the Western States. Am. Jour. Sci., vol. 45, 1843, pp. 151, 152, 163–165.

1844.

EMMONS, E. The Taconic System; based on Observations in New York, Massachusetts, Vermont, and Rhode Island. Albany, 1844, pp. vii, 67, 6 pls.

HALL, JAMES. Geological Survey of New York; its Influence on the Productive Pursuits of the Community. New York State Agr. Soc. Trans. for 1843, 1844, pp. 241–277.

JACKSON, C. T. Final Report on the Geology and Mineralogy of the State of New Hampshire, with Contributions towards the Improvement of Agriculture and Metallurgy. Concord, 1844, pp. viii, 376.

ROGERS, HENRY D. On American Geology and Present Condition of Geological Research in the United States. Am. Jour. Sci., vol. 47, 1844, pp. 137–161, 247–278.

ROGERS, W. B. A System of Classification and Nomenclature of the Paleozoic Rocks of United States, with an Account of their Distribution more Particularly in the Appalachian Mountain Chain. Am. Jour. Sci., vol. 47, 1844, pp. 111, 112.

1845.

ADAMS, C. B. First Annual Report on the Geology of Vermont. Burlington, 1845, pp. 92.

BAYFIELD, H. W. On the Junction of the Transition and Primary Rocks of Canada and Labrador. Quart. Jour. Geol. Soc., London, vol. 1, 1845, pp. 450–459.

GESNER, A. Geological Map of Nova Scotia. (Accompanying papers by J. W. Dawson and Richard Brown.) Quart. Jour. Geol. Soc., London, vol. 1, 1845, oppo. p. 23.

HALL, JAMES. Nature of the Strata and Geographical Distribution of the Organic Remains in the Older Formations of the United States. Boston Jour. Nat. Hist., vol. 5, 1845, pp. 1–20.

LOGAN, W. E. (Account of General Structure of an Extended Area in North America.) Geol. Survey Canada, Report of Progress for 1843. 1845.

LYELL, CHAS. Travels in North America. New York, 1845, vol. 1, pp. 251, vol. 2, pp. 231.

1846.

ADAMS, C. B. Second Annual Report on the Geology of the State of Vermont. Burlington, 1846, pp. 267.

BARRANDE, J. Notice Préliminaire sur le Système Silurien et les Trilobites de Bohême, Leipsig, 1846.

ROGERS, H. D. On the Mineralogy and Geology of the South Shore of Lake Superior. Boston Soc. Nat Hist., Proc., vol. 2, 1846, pp. 124, 125.

1847.

ADAMS, C. B. Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, pp. 32. (See foot-note on page 31).

——— On the Taconic System. Am. Jour. Agri. and Sci., vol. 6, 1847, p. 260 (corrected pagination).

EMMONS, E. [On the Taconic system.] Am. Jour. Agri. and Sci., vol. 6, 1847, p. 260 (corrected pagination).

——— Agriculture of New York, vol. 1. Albany (1846), 1847, pp. 371, pls. 21, map.

HALL, JAMES. Paleontology of New York, vol. 1, Containing Descriptions of the Organic Remains of the Lower Division of the New York System. Albany, 1847, pp. xxiii, 338, pls.

——— *Letter* on Certain Fossils in the Red Sandrock of Highgate. Third Annual *Report* on the Geology of the State of Vermont. Burlington, 1847, p. 31.

HOUGH, FRANKLIN B. Observations on the Geology of Lewis County, New York. Am. Jour. Agri. and Sci., vol. 5, 1847, pp. 267–274, 314–327.

LOGAN, W. E. Report on Sequence and Distribution of the Formations [on the Ottawa]. Geol. Surv. Canada, Rep. Progress for 1845–6. Montreal, 1847, pp. 40–75.

VERNEUIL, ED. DE. Note sur le parallelisme des roches des dépôts paléozoïques de l'Amérique Septentrionale avec ceux de l'Europe, suivi d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des étages où elles se rencontrent, et terminé par un examen critique de chacune de ces espèces. Soc. géol. France, Bull., 2e sér., vol. 4, 1847, pp. 646–709. Translated with annotations by Prof. James Hall, Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 176–183, 359–370; vol. 7, 1849, pp. 45–51, 218–231.

1848.

ADAMS, C. B. On the Taconic Rocks. Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 108–110.

OWEN, D. D. (Letter on Geology of Wisconsin Territory.) Soc. géol. France. Bull. 2e sér., vol. 5, 1848, pp. 294–296.

——— Report of a Geological Reconnoissance of the Chippewa Land District of Wisconsin; and Incidentally of a Part of Iowa and of the Minnesota Territory. Letter of the Secretary of the Treasury Communicating a Report of a Geological Reconnoissance of the Chippewa Land District of Wisconsin (etc), by D. D. Owen, Thirtieth Congress, first session. Senate Ex. Doc. No. 57. 1848. pp. 3–72, map, plates.

1849.

BURT, WILLIAM M. Topography and Geology of the Survey, with reference to mines and minerals, of a District of Township Lines South of Lake Superior in 1845. Message President United States, Thirty-first Congress, first session, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 811–832.

FOSTER, J. W. Notes on the Geology and Topography of Portions of the Country Adjacent to Lakes Superior and Michigan, in the Chippewa Land District. Message from President of United States to Congress, Thirty-first Congress, first session, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 773–785.

FOSTER, J. W., and J. D. WHITNEY. Synopsis of the Explorations of the Geological Corps in the Lake Superior Land District in the Northern Peninsula of Michigan. Message from the President of United States to Congress, Thirty-first Congress, first session, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 605-625, 3 maps.

GESNER, ABRAHAM. The Industrial Resources of Nova Scotia. Halifax, N. S., 1849, pp. 341, and Appendix, p. 15.

HUBBARD, BELA. General Observations upon the Geology and Topography of the District South of Lake Superior, Subdivided in 1845, under Houghton. Message from President of United States, Thirty-first Congress, first session, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 833–842.

JACKSON, C. T. Message of President of United States to Congress. Thirty-first Congress, first session, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 371–502.

LOGAN, W. E. Canadian Geological Survey, Report Progress for 1847–'48, 1849.

ROEMER, FERD. Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes nach eigener Beobachtung geschildert. Bonn, 1849, pp. 464, map.

WHITE, GEORGE. Statistics of the State of Georgia. Savannah, 1849, pp. 624 and 77, map.

1850.

DAWSON, J. W. On the Metamorphic and Metalliferous Rocks of Eastern Nova Scotia. Quart. Jour. Geol. Soc., London, vol. 6, 1850, pp. 347–364.

FITCH, ASA, M. D. A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850, pp. 753–944.

FOSTER, J. W., and J. D. WHITNEY. [Aperçu de l' ensemble des terrains Siluriens du lac Superieur.] Soc. géol. France, Bull., 2e sér., vol. 8, 1850, pp. 89–100.

——— Report on the Geology and Topography of a Portion of the Lake Superior Land District in the State of Michigan. Part I. Washington, 1850. Stratified and Sedimentary Rocks. Chapter 4, pp. 99–122.

HOUGH, FRANKLIN B. Catalogue of Mineralogical and Geological Specimens Received from F. B. Hough. Third Annual Rep. of Regts. Univ. State Cab. Nat. Hist. 1850, pp. 31–33.

——— On the Cylindrical Structure Observed in Potsdam Sandstone. Am. Assoc. Proc., vol. 4, 1850, pp. 352–354.

JOHNSTON, J. F. W. Report on the Agricultural Capabilities of the Province of New Brunswick. Fredericton, 1850, pp. 262.

LOGAN, W. E. Report on Bay St. Paul and Murray Bay. Geol. Sur. Canada, Rept. Progress for 1849–'50. Toronto, 1850, pp. 7–31.

——— Report on Rocks on South Side of the St. Lawrence. Geol. Sur. Canada, Rept. Progress for 1849–'50. Toronto, 1850, pp. 31–72.

MARCOU, JULES. Réponse à la lettre de MM. Foster et Whitney sur le lac Supérieur. Soc. géol., France, Bull. 2e sér., vol. 8, 1850, pp. 101–105.

ROBB, JAMES. (Letter on the Geological Structure of New Brunswick.) Report on the Agricultural Capabilities of the Province of New Brunswick, by J. F. W. Johnston, Fredericton, 1850, pp. 12, 13.

1851.

DESOR, E. [Potsdam Sandstone on the River St. Croix.] Boston Soc. Nat. Hist. Proc., vol. 3, 1851, p. 202.

FOSTER, J. W., and J. D. WHITNEY. On the Age of the Sandstone of Lake Superior, with a Description of the Phenomena of Igneous Rocks. Am. Assoc. Proc., vol. 5, 1851, pp. 22–39.

——— Lower Silurian System. Potsdam and Calciferous Sandstones. Rept. on Geol. of Lake Superior Land District, part 2, 1851, pp. 110–139.

HALL, JAMES. [Geological Investigations on Drummond's Island and the North Shores of Lakes Huron and Michigan, etc.] Am. Acad. Proc., vol. 2, 1851, pp. 253, 254.

——— Description of New or Rare Species of Fossils from the Palæozoic Series. Rept. on the Geology of the Lake Superior Land District, by Foster and Whitney, part 2, 1851, pp. 203–231.

——— Parallelism of the Palæozoic Deposits of the United States and Europe. Rept. on the Geology of the Lake Superior Land District, by Foster and Whitney, part 2, 1851, pp. 285–318.

JACKSON, C. T. [Some Observations on the Age of the Sandstones of the United States.] Boston Soc. Nat. Hist., Proc., vol. 3, 1851, pp. 335, 336, 337–339.

KING, H. Some Remarks on the Geology of the State of Missouri. Am. Assoc. Proc., vol. 5, 1851, pp. 182–199.

LAPHAM, I. A. On the geology of the southeastern portion of the State of Wisconsin; being the part not surveyed by the United States geologists. Rept. on the geology of the Lake Superior land district by Foster and Whitney, part 2, 1851, pp. 167–172.

LOGAN, W. E. On the occurrence of a track and footprints of an animal in the Potsdam sandstone of Lower Canada. Quart. Jour. Geol. Soc., London, vol. 7, 1851, pp. 247–257.

OWEN, D. D. On the paleontology of the lowest sandstones of the Northwest. Am. Assoc., Proc., vol. 5, 1851, pp. 169–172.

PROUT, H. A. Description of a new Graptolite found in the lower Silurian rocks near the Falls of the St. Croix River. Am. Jour. Sci., 2d ser., vol. 11, 1851, pp. 187–191.

WHITTLESEY, CHARLES. Remarks upon the section from the Falls of Wolf River, through Navarino to Lake Michigan. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, pp. 174–177.

——— The dip, bearing, and thickness of the Silurian groups. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, pp. 177–189.

1852.

BARRANDE, J. Système de la Bohême, vol. 1, 1852, p. 88.

HUNT, T. S. Remarks on the lithological and paleontological characters of the Potsdam sandstone. Am. Assoc., Proc., vol. 6, 1852, pp. 271–273.

LOGAN, W. E. Report [on country between Riviere du Nord and Beauharnois]. Geol. Survey of Canada. 1851–'52, 1852, pp. 5–56.

——— On the age of the copper-bearing rocks of Lakes Superior and Huron, etc. British Assoc. Rep. for 1851–'52, Trans. of sections pp. 59–62. Am. Jour. Sci., 2d ser., vol. 14, 1852, pp. 224–229.

——— *On the footprints* occurring in the Potsdam sandstone of Canada. Quart. *Jour. Geol.* Soc. London, vol. 8, 1852, pp. 199–208.

MURRAY, ALEX. Report [of country lying between rivers Ottawa and St. Lawrence]. Geol. Survey of Canada for 1851–'52, 1852, pp. 57–91.

NORWOOD, J. C. Description of the geology of middle and western Minnesota, including the country adjacent to the northwest and part of the southwest shore of Lake Superior. Rep. Geol. Survey of Wis., Iowa, and Minn., and incidentally of a portion of Nebraska Territory, by D. D. Owen, Philadelphia, 1852, pp. 215–418.

OWEN, D. D. Geol. Survey of Iowa, Minnesota, and Wisconsin, and incidentally of a portion of Nebraska Territory, Philadelphia, 1852, pp. xvii–xxxviii, 39–206, plates.

OWEN, RICHARD. Description of the impressions and footprints of the Protichnites from the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc. London, vol. 8, 1852, pp. 214–225.

ROEMER, FERD. Die Kreidebildungen von Texas und ihre organischen Einschlusse, Bonn, 1852, pp. 100.

SEDGWICK, ADAM. On the classification and nomenclature of the Lower Paleozic rocks of England and Wales. Quart. Jour. Geol. Soc. London, vol. 8, 1852, pp. 136–168.

SHUMARD, B. F. Local details of geologic sections on the St. Peter's, Mississippi, Wisconsin, Baraboo, Snake, and Kettle Rivers. Report of a geological survey of Wis., Iowa, and Minn., and incidentally of a portion of Nebraska Territory, by D. D. Owen, Philadelphia, 1852, pp. 475–531, pls.

1853.

BARRANDE, J. [Silur-Fauna im Wisconsin und im New York.] Neues Jahrbuch für Miner., 1853, pp. 335–347.

——— [Silur-Gebilde im Texas und am Oberen-See.] Neues Jahrbuch für Miner., 1853, pp. 446, 447.

BIGSBY, J. J. On the geology of Quebec and its environs. Quart. Jour. Geol. Soc., London, vol. 9, 1853, pp. 82–101.

LESLEY, J. P. [Report on Hiwassee copper region.] First annual report of the board of directors of the Hiwassee Mining Company, made May 11, 1853. New York, 1853, pp. 12–19.

SALTER, J. W., and W. T. AVELINE. On the "Caradoc sandstone" of Shropshire. Quart. Jour. Geol. Soc. London, vol. 9, 1853, pp. 62–73.

THOMPSON, ZADOCK. Geology of Vermont. Natural History of Vermont. Burlington, 1853, Appendix, pp. 40–58.

1854.

HUNT, T. S. On some of the crystalline limestones of North America. Am. Jour. Sci., 2d ser., vol. 18, 1854, pp. 193–200.

LOGAN, W. E. [Exploration on the north side of the St. Lawrence, between Montreal and Cape Tourmente.] Geol. Surv. Canada, Rep. progress for 1852–'53, 1854, pp. 5–74.

MURRAY, ALEX. [Exploration between Kingston and Lake Simcoe.] Geol. Surv. Can., Rep. progress for 1852–'53, 1854, pp. 75–152.

1855.

DAWSON, J. W. Acadian Geology, first edition. Edinburgh, 1855, pp. 384.

LAPHAM, I. A. Geological map of Wisconsin. Milwaukee, 1855.

LOGAN, W. E. [Sur la formation silurique des environs de Québec.] Soc. géol. France, Bull., 2e sér., vol. 12, 1855, pp. 504–508.

SCHOOLCRAFT, H. R. Observations on the geology and mineralogy of the region embracing the sources of the Mississippi River and the Great Lake basins during the expedition of 1820. Schoolcraft's Mississippi River, Phila., 1855, pp. 303–362. Reprint from report made in 1820.

SWALLOW, G. C. Geology of Missouri. [Silurian system.] Geol. Survey Missouri, 1st and 2d Ann. Repts, part 1, 1855, pp. 107–133.

WHITNEY, J. D. Remarks on some points connected with the geology of the north shore of Lake Superior. Am. Assoc. Proc., vol. 9, 1855, pp. 204–209.

1856.

EMMONS, EBENEZER. American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. *Albany*, 1856. Vol. 1, pt. 2.

——— Geological report of the midland counties of North Carolina. New York and Raleigh, 1856, pp. xx, 347, map and 12 pls.

JACKSON, C. T. [On the Braintree argillite and its trilobites.] Boston Soc. Nat. Hist., Proc., vol. 6, 1856, pp. 42–44.

PERCIVAL, JAMES G. Annual report of the geological survey of the State of Wisconsin. Madison, 1856, pp. 111.

ROGERS, W. B. Proofs of the Protozoic age of some of the altered rocks of eastern Massachusetts from fossils recently discovered. Am. Acad., Proc., vol. 3, 1856, pp. 315–318.

——— [On trilobites from Braintree and on the geological relations of the district.] Boston Soc. Nat. Hist., Proc., vol. 6, 1856, pp. 27–29, 40, 41.

——— Discovery of Paleozoic fossils in eastern Massachusetts. Am. Jour. Sci., 2d ser., vol. 22, 1856, pp. 296–298.

SAFFORD, J. M. A geological reconnaissance of Tennessee, 1st biennial report. Nashville, 1856, pp. 154 and map.

1857.

ENGELMANN, H. Report of a geological exploration from Fort Leavenworth to Bryan's Pass, made in connection with the survey for a road from Fort Riley to Bridger's Pass, under Bryan. Rept. Sec. of War, Appendix H, 1857, pp. 489–517.

ROGERS, H. D. On the correlation of the North American and British Paleozoic strata. British Assoc. Adv. Sci., vol. 26, 1857, Trans. Sec., pp. 175–186.

1858.

BIGSBY, JOHN J. On the Paleozoic basin of the State of New York. Part I. A synoptical view of the mineralogical and fossil characters of the Paleozoic strata of the State of New York. Quar. Jour. Geol. Soc., London, vol. 14, pp. 335–427.

——— Part II. Classification of the Paleozoic strata of the State of New York, Ibid. pp. 427–452.

HALL, JAMES. Geology of Iowa, vol. 1, 1858, pp. 35–146, 473–724.

HAYDEN, F. V. Explorations under the War Department. Explanations of a second edition of a geological map of Nebraska and Kansas, based upon information obtained in an expedition to the Black Hills, under command of Lieut. G. K. Warren, topographical engineer, U. S. Army. Am. Jour. Sci., 2d ser., vol. 26, 1858, pp. 276–278.

LEA, ISAAC. [On the trilobite formation at Braintree, Massachusetts.] Phila. Acad. Sci., Proc., vol. 9, 1858, p. 205.

MEEK, F. B., and F. V. HAYDEN. Fossils of Nebraska. Letter from F. B. Meek and F. V. Hayden. Am. Jour. Sci., 2d ser., vol. 25, 1858, pp. 439–441.

ROGERS, HENRY DARWIN. The geology of Pennsylvania. Two vols. Philadelphia, 1858. Vol. 1, pp. 596, and pls; vol. 2, pp. 1046 and 30 pls., and atlas of 2 maps and 2 pls.

TUOMEY, M. Second biennial report on the geology of Alabama, Montgomery, 1858, pp. 168 and pl.

WHITNEY, J. D. Geol. Surv. Iowa, vol. 1, 1858, pp. 259–472.

1859.

BIGSBY, JOHN J. On the Paleozoic basin of the State of New York. Part III. An inquiry into the sedimentary and other external relations of the Paleozoic fossils of the State of New York. Quar. Jour. Geol. Soc. London, vol. 15, 1859, pp. 251–335.

DANIELS, EDWARD. [Notes on geology of Wisconsin and adjacent States.] Boston Soc. Nat. Hist., Proc., vol. 6, 1859, pp. 309, 310.

HALL, JAMES. Remarks upon the trilobites of the shales of the Hudson River group. Palæontology of New York, vol. 3, supplement to vol. 1, 1859, pp. 525–529.

HAYDEN, F. V. Explorations under the War Department. Explanations of a second edition of a geological map of Nebraska and Kansas, based upon information obtained in an expedition to the Black Hills, under command of Lieut. G. K. Warren, topographical engineer, U. S. Army. Phila. Acad. Sci., Proc., vol. 10, 1859, pp. 139–158.

HITCHCOCK, EDWARD. [Catalogue of State cabinet and notes on metamorphic rocks.] Sixth annual report of the secretary of Massachusetts Board of Agriculture, *etc., by Charles L.* Flint, Boston, 1859, pp. iii–lxix.

JACKSON, C. T. [On a trilobite from Braintree.] Boston Soc. Nat. Hist., Proc., vol. 7, 1859, p. 54.

MEEK, F. B., and F. V. HAYDEN. [Some remarks on the geology of the Black Hills and portions of the surrounding country.] Phila. Acad. Sci., Proc., vol. 10, 1859, pp. 41–49, map.

SALTER, J. W. On the fossils of the lingula-flags or "zone primordiale." Quar. Jour. Geol. Soc, London, vol. 15, 1859, pp. 551–555.

SHUMARD, B. F. Letter touching the late discovery of Lower Silurian rocks, equivalent to the Potsdam sandstone and Calciferous sandrock of the New York system, in Burnet County, Texas. Trans. Acad. Sci., St. Louis, vol. 1, 1859, pp. 672, 673.

1860.

BARRANDE, J. Trilobiten der Primordial-Fauna in Massachusetts. Neues Jahrb., für Miner, 1860, pp. 429–431.

BILLINGS, E. On some new species of fossils from the limestone near Point Levi, opposite Quebec. Canadian Naturalist, vol. 5, 1860, pp. 301–324.

——— [Review of] Acadian Geology, and a Supplementary Chapter thereto. Canadian Naturalist, vol. 5, 1860, pp. 450–455.

BRADLEY, F. H. Description of a New Trilobite from the Potsdam Sandstone. Am. Jour. Sci., 2d ser., vol. 30, 1860, pp. 241, 242.

DAWSON, J. W. Supplementary Chapter to Acadian Geology, Edinburgh, 1860, pp. 70.

HALL, JAMES. Note upon the trilobites of the shales of the Hudson River group, in the town of Georgia, Vt. Thirteenth Ann. Rep. State Cab. Nat. Hist., 1860, pp. 113–119. Report upon the Geology of Vermont, vol. 1, 1861, pp. 367–372.

LOGAN, SIR W. E. On the track of an animal lately found in the Potsdam formation. Canadian Naturalist, vol. 5, 1860, pp. 279–285.

MARCOU, JULES; JOACHIM BARRANDE and. On the Primordial fauna and the Taconic system; with additional notes by Jules Marcou. Boston Soc. Nat. Hist., Proc., vol. 7, 1860, pp. 369–382; Am. Jour. Sci., 2d ser., vol. 31, 1860, pp. 212–215; Canadian Naturalist, vol. 6, 1860, pp. 108–112.

TYSON, PHILIP T. First Report of the State Agricultural Chemist of Maryland. Annapolis, 1860, pp. 145 and 20, map.

1861.

BARRANDE, J. Documents anciens et nouveaux sur la faune primordiale et le système taconique en Amérique. Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 203–321.

BILLINGS, E. On the Age of the Red Sándstone Formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

HALL, JAMES. On the Primordial fauna and Point Levi fossils. Am. Jour. Sci., 2d ser., vol. 31, 1861, pp. 220–226. Canadian Naturalist, vol. 6, 1861, pp. 106–120.

——— Report of the Superintendent of the Geological Survey [of Wisconsin] Exhibiting the progress of the work. January 1, 1861. Madison, 1861, pp. 52.

——— Correction for the 13th Annual Report. Fourteenth Ann. Rep. State Cab. Nat. Hist., 1861, p. 110.

HAYDEN, F. V. Sketch of the geology of the country about the headwaters of the Missouri and Yellowstone rivers. Am. Jour. Sci., 2d ser., vol. 31, 1861, pp. 229–245.

HITCHCOCK, C. H. Hypozoic and Paleozoic rocks. Report on the geology of Vermont, descriptive, theoretical, economical, and scenographical, vol. 1, 1861, pp. 257–294. Notes on the Sections, vol. 2, 1861, pp. 595–682.

——— [On the Geology of Vermont, chiefly in connection with the Taconic system.] Boston Soc. Nat. Hist., Proc., vol. 7, 1861, pp. 426, 427.

——— General Report on the Geology of Maine. Prelim. Rep. on the Natural History and Geology of Maine. Augusta, 1861, pp. 146–328.

HUNT, T. STERRY. On some points in American geology. Am. Jour. Sci., 2d ser., vol. 31, 1861, pp. 392–414. Canadian Naturalist, vol. 6, 1861, pp. 81–105.

JACKSON, C. T. [On a trilobite from Braintree.] Boston Soc. Nat. Hist., Proc., vol. 8, 1861, p. 58.

LOGAN, W.E. Remarks on the fauna of the Quebec group of rocks and the Primordial zone of Canada. Canadian Naturalist, vol. 5, 1860, pp. 472–477; vol. 6, 1861, pp. 106–120; Am. Jour. Sci., 2d ser., vol. 31, 1861, pp. 216–220. Remarques sur la faune des roches du groupe de Québec et sur la zone primordiale du Canada. Soc. géol., France, Bull., 2e sér., vol. 18, 1861, pp. 309–914.

MARCOU, JULES. The Taconic and Lower Silurian rocks of Vermont and Canada. Boston Soc. Nat. Hist., Proc., vol. 8, 1861, pp. 239–253.

MEEK, F. B., and F. V. HAYDEN. Descriptions of new Lower Silurian (Primordial) Jurassic, Cretaceous, and Tertiary Fossils, collected in Nebraska; with some remarks on the rocks from which they were obtained. Phila. Acad. Sci., Proc., vol. 13, 1861, pp. 415–447.

NEWBERRY, J. S. Geological Report. Report upon the Colorado River of the West, explored in 1857–'58 by Lieut. J. C. Ives. Part III, 1861, pp. 154.

ORDWAY, ALBERT. On the occurrence of other fossil forms at Braintree, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 8, 1861, pp. 5, 6.

ROGERS, WILLIAM B. [Notes on the geological structure of western Vermont.] Report on the geology of Vermont, vol. 1, 1861, pp. 326, 327.

——— [On fossiliferous pebbles of Potsdam rocks in Carboniferous conglomerate north of Fall River, Massachusetts.] Boston Soc. Nat. Hist., Proc., vol. 7, 1861, pp. 389–391.

——— Remarks on the geology of the neighborhood of St. John, New Brunswick. Boston Soc. Nat. Hist.. Proc., vol. 7, 1861, p. 176.

SHUMARD, B. F. [Letter on the Primordial of Texas.] Soc. géol. France, Bull., 2e sér. vol. 18, 1861, pp. 218, 219.

——— The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci., 2d ser., vol. 32, 1861, pp. 213–221.

WINCHELL, A. Geology. [General sketch.] Geol. Surv. Michigan, 1st Biennial Rep. of Prog., Lansing, 1861, pp. 21–141.

1862.

AGASSIZ, LOUIS. [On the difference between faunas of zoological and geological periods.] Boston Soc. Nat. Hist., Proc., vol. 8, 1862, p. 58.

BILLINGS, E. On Prof. J. Hall's claim to priority in the determination of the age of the Red Sandrock series of Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 370–376.

——— Further observations on the age of the Red Sandrock formation (Potsdam Group) of Canada and Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 100–105. (See note and corrections, same vol., pp. 421, 422.)

DAWSON, J. W. On the flora of the Devonian period in Northeastern America. Quart. Jour. Geol. Soc., London, vol. 18, 1862, pp. 296–330.

HALL, JAMES. Physical geography and general geology. Geol. Survey Wisconsin, vol. 1, 1862, pp. 1–72, maps.

——— On a new crustacean from the Potsdam sandstone. Canadian Naturalist, vol. 7, 1862, pp. 443–445.

——— Supplementary note to the 13th Ann. Rep. State Cab. Nat. Hist., New York. Fifteenth Ann. Rep. State Cab. Nat. Hist., New York, 1862, p. 114.

——— [Letter on the Primordial of America.] Soc. géol. France., Bull., 2e sér., vol. 19, 1862, pp. 725–734.

——— On the Potsdam sandstone and Hudson River rocks in Vermont. Am. Jour. Sci., 2d. ser., vol. 33, 1862, pp. 106–108.

HAYDEN, F. V. The Primordial sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 68–79. Canadian Journal, new ser., vol. 7, 1862, pp. 149–151.

HITCHCOCK, C. H. Reports on the Geology of Maine. Second Annual report on the natural history and Geology of Maine. Augusta, 1862, pp. 223–264, 266–312, 323–332, 343–352, 377–382, 388–395, 401–405, 422–430, map.

——— Fossils of the Potsdam Group in North America. Portland Soc. Nat. Hist., Proc. vol. 1, 1862, pp. 87–90.

JUKES, J. BEETE. The Student's Manual of Geology. Second edition, Edinburgh, 1862, pp. xx, 764.

MARCOU, JULES. [The slate of Nova Scotia metamorphic Taconic rock.] Boston Soc. Nat. Hist., Proc., vol. 9, 1862, p. 47.

OWEN, RICHARD. Preliminary observations. General report and description by counties. [Lower and Upper Silurian.] Geological reconnaissance of Indiana, made in 1859–'60, Indianapolis, 1862, pp. 3–26, 30–91.

SHUMARD, B. F. Notice of some new and imperfectly known fossils from the Primordial Zone (Potsdam and Calciferous sand group) of Wisconsin and Missouri. St. Louis Acad. Sci. Trans., vol. 2, 1862, pp. 101–107.

WHITNEY, J. D. [Stratigraphical geology.] Geol. Survey Wisconsin, vol. 1, 1862, pp. 140–192.

1863.

BIGSBY, J. J. On the Cambrian and Huronian formations. Quart. Jour. Geol. Soc. London, vol. 19, 1863, pp. 36–52.

CAMPBELL, J. Report on the Gold Fields of Nova Scotia. Halifax, 1863, pp. 12.

COOK, GEORGE H. Report of Prof. George H. Cook upon the geological survey of New Jersey, and its progress during the year 1863, pp. 13.
DANA, JAMES D. Manual of geology, 1st ed., New Haven, 1863.
DEVINE, T. Description of a new trilobite from the Quebec group. Canadian Naturalist, vol. 8, 1863, pp. 95–98: 210, 211.
HALL, JAMES. Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Regents Univ. State Cab. Nat. Hist., 1863, pp. 119–220. Albany Inst., Trans., vol. 5, 1867, pp. 93–195.
HAYDEN, F. V. On the geology and natural history of the Upper Missouri. Am. Philos. Soc. Trans., new ser., vol. 12, 1863, pp. 1–217, with map.
LOGAN, W. E. Geological Survey of Canada; Report of Progress from its Commencement to 1863. Montreal, 1863, pp. 983.
MATTHEW, G. F. Observations on the geology of St. John County, New Brunswick. Canadian Naturalist, vol. 8, 1863, pp. 241–259.
WHITTLESEY, CHARLES. The Penokie Mineral Range, Wisconsin. Boston Soc. Nat. Hist., Proc., vol. 9, 1863, pp. 235–244.

1864.

MEEK, F. B., and F. V. HAYDEN. Paleontology of the Upper Missouri; a report upon collections made principally by the expeditions under command of Lieut. G. K. Warren in 1855–'56. Invertebrates. Smithsonian Contributions, No. 172, 1864, pp. 136, plates.
WINCHELL, ALEXANDER. Notice of a small collection of fossils from the Potsdam sandstone of Wisconsin and Lake Superior sandstone of Michigan. Am. Jour. Sci., 2d ser., vol. 37, 1864, pp. 226–232.

1865.

BAILEY, L. W. Observations on the geology of Southern New Brunswick. Fredericton, 1865, pp. 1–30, 31–122.
BAILY, W. H. The Cambrian rocks of the British Islands, with especial reference to the occurrence of this formation and its fossils in Ireland. Geol. Magazine, vol. 2, 1865, pp. 385–400.
BILLINGS, E. Paleozoic Fossils, vol. I. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860–'65. Montreal, 1865, pp. 426. (Of this volume pp. 1–24 were issued in Nov., 1861; pp. 25–56 issued Jan. 1862; pp. 57–168 issued in June, 1862; pp. 169–344 issued Feb., 1865; pp. 395–416 published in Canadian Naturalist, vol. 5, 1860, pp. 301–324.)
HARTT, C. FRED. Preliminary notice of a fauna of the Primordial period in the vicinity of St. John, N. B. Observations on the geology of southern New Brunswick. 1865, pp. 30, 31.
LOGAN, W. E. Geological Survey of Canada. Atlas of maps and sections with an Introduction and Appendix. [To accompany report of Progress from commencement to 1863.] Montreal, 1865, 11 maps and sections.
MATTHEW, G. F. On the Azoic and Paleozoic rocks of southern New Brunswick. Quart. Jour. Geol. Soc., London, vol. 21, 1865, pp. 422–434, map. Canadian Naturalist, new ser., vol. 3, 1865, pp. 387–391.

1866.

LOGAN, W. E. Lower Silurian Rocks of North America. Geol. Surv. Newfoundland, Rep. Prog. for 1864, Montreal, 1866, pp. 45, 46. Revised ed. 1881, pp. 47–50.
——— Report for 1866. Geol. Surv. Canada. Rep. of Prog. 1863 to 1866; 1866, pp. 3–27.
LOGAN, W. E., and JAMES HALL. Geological map of Canada and part of the United States, from Hudson's Bay to Virginia and from the Missouri River to Newfoundland. Montreal, 1866.
MURRAY, ALEXANDER. Sequence and distribution of the rocks of the great Northern Peninsula. Geol. Survey Newfoundland. Rep. of Prog. for 1864. Montreal, 1866, pp. 10, 44. Revised edition 1881, pp. 5–47.

1867.

DAWSON, J. W. On recent geological discoveries in the Acadian provinces of British America. Am. Assoc., Proc., vol. 16, 1867, pp. 117–119. Canadian Naturalist, new ser., vol. 3, 1868, pp. 295–297.

HITCHCOCK, C. H. The Winooski marble of Colchester, Vermont. Am. Assoc., Proc., vol. 16, 1867, p. 119.
——— The geology of Vermont. Am. Assoc., Proc., vol. 16, 1867, pp. 120–122.
LYMAN, B. S. On the Lower Silurian brown hematite beds of America. Am. Assoc., Proc., vol. 16, 1867, pp. 114–117.
MACFARLANE, THOMAS. On the geological formations of Lake Superior. Canadian Naturalist, new ser., vol. 3, 1867–'68, pp. 177–201, 241–256.
PERRY, JOHN P. The red sandstone of Vermont and its relations. Am. Assoc., Proc., vol. 16, 1867, pp. 128–134.

1868.

AGASSIZ, ALEXANDER. On the position of the sandstone of the southern slope of a portion of Keweenaw Point, Lake Superior. Boston Soc. Nat. Hist., Proc., vol. 11, 1868, pp. 244–246.
COOK, GEORGE H. Geology of New Jersey. (With 13 maps in portfolio and 7 pls. bound in volume.) Newark, 1868, pp. 900.
DAWSON, J. W. Acadian geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, 2d ed., London, 1868, pp. xxvi, 694, map.
HARTT, C. FRED. Fossils of the Primordial or Acadian group at St. John. In Dawson, Acadian geology, 1868, pp. 641–657.
HUNT, T. STERRY. On some points in the geology of Vermont. Am. Jour. Sci., 2d ser., vol. 46, 1868, pp. 222–229.
MEEK, F. B. Preliminary notice of a remarkable new genus of corals, probably typical of a new family * * * from the Silurian rocks of Nevada Territory. Am. Jour. Sci., 2d ser., vol. 45, 1868, pp. 62–64.
——— Note on Ethmophyllum and Archeocyathus. Am Jour. Sci., 2d ser., vol 46, 1868, p. 144.
MURRAY, ALEXANDER. Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868, St. Johns, 1868, pp. 68. Revised edition, 1881, pp. 137–186.
PERRY, JOHN P. Queries on the red sandstone of Vermont and its relations. Boston Soc. Nat. Hist., Proc., vol. 11, 1868, pp. 341–353.

1869.

HAYDEN, F. V. Geological Report of the Exploration of the Yellowstone and Missouri Rivers, under the direction of Capt. W. F. Raynolds, 1859–'60. Washington, 1869, pp. 144, with a geological map.
HIND, H. Y. Report on the Waverly Gold District, with geological maps and sections. Halifax, 1869, pp. 62.
KERR, W. C. Report of the State Geologist of North Carolina. Raleigh, 1869, pp. 57.
LAPHAM, I. A. Geological map of Wisconsin. Milwaukee, 1869.
MARSH, O. C. Description of a new species of Protichnites from the Potsdam sandstone of New York. Am. Jour. Sci., 2d ser., vol. 48, 1869, pp. 46–49.
MATTHEW, G. F., and L. W. BAILEY. Remarks on the age and relations of the metamorphic rocks of New Brunswick and Maine. Am. Assoc. Proc., vol. 18, 1869, pp. 179–195. Canadian Naturalist, new ser., vol. 4, 1869, pp. 326–328.
SAFFORD, JAMES M. Geology of Tennessee. Nashville, 1869, pp. 551, 7 pls. and map.
SHALER, N. S. [On the relations of the rocks in the vicinity of Boston.] Boston Soc. Nat. Hist., Proc., vol. 13, 1869, pp. 172–178.

1870.

HIND, H. Y. Preliminary Report on a Gneissoid Series Underlying the Gold-bearing Rocks of Nova Scotia, and supposed to be the equivalent of the Laurentian system. Halifax, N. S., 1870, pp. 14.
——— Report on the Sherbrooke Gold District, together with a paper on the gneisses of Nova Scotia, and an abstract of a paper on gold mining in Nova Scotia. Halifax, N. S., 1870, pp. 79.
——— On two gneissoid series in Nova Scotia and New Brunswick, supposed to be the equivalents of the Huronian (Cambrian) and Laurentian. Quart. Jour. Geol. Soc., London, vol. 26, 1870, pp. 468–479.
——— On the Laurentian and Huronian series in Nova Scotia and New Brunswick. Am. Jour. Sci., 2d ser., vol. 49, 1870, pp. 347–355.
HITCHCOCK, C. H. The geology of Vermont. In geology of northern New England, 1870, pp. 5. Note added May 25, 1882.
HUNT, T. STERRY. On the geology of Eastern New England. Am. Jour. Sci., 2dser., vol. 50, 1870, pp. 83–90.

MEEK, F. B. Descriptions of fossils collected by the United States Geological Survey under the charge of Clarence King, esq. Phila. Acad. Sci., Proc., vol. 22, 1870, pp. 56–64.

MURRAY, ALEXANDER. Of the rocks and associated minerals [of Bonavista Bay, etc.]. Report upon the geological survey of Newfoundland for 1869, St. Johns, 1870. Revised edition, 1881, pp. 194–205.

RICHARDSON, JAMES. Report on the south shore of the St. Lawrence, below Quebec. Geol. Surv. Canada, report progress for 1866 to 1869, 1870, pp. 119–141, map.

WHITE, C. A. General geology. Azoic, Lower Silurian, Upper Silurian, and Devonian systems. Geol. Survey Iowa, vol. 1, Des Moines, 1870, pp. 167–188.

1871.

FORD, S. W. Notes on the primordial rocks in the vicinity of Troy, N. Y. Am. Jour. Sci., 3d ser., vol. 2, 1871, pp. 32–34. Canadian Naturalist, new ser., vol. 6, 1872, pp. 209–213.

HAYDEN, F. V. Report of F. V. Hayden [on the geological survey of Wyoming]. U. S. Geol. Surv. of the Terr., 4th Ann. Report, 1871, pp. 11–81.

HUNT, T. S. On the geology of the vicinity of Boston. Boston Soc. Nat. Hist., Proc., vol. 14, 1871, pp. 45–49.

MEEK, F. B. Notice of a new brachiopod from the lead-bearing rocks at Mine La Motte, Missouri. Phila. Acad. Nat. Sci., Proc., vol. 23, 1871, pp. 185–187.

MURRAY, ALEXANDER. Of Primordial Silurian and related formations. Rep. Geol. Surv. N. F. for 1870, St. Johns, 1870 [1871], pp. 30–43. Revised edition, London, 1881, pp. 232–241.

SWALLOW, G. C. Remarks on the geological map and section of the rocks of Missouri. American Naturalist, vol. 5, 1871, pp. 541, 542. Am. Asso., Proc., vol. 20, 1871, p. 262.

1872.

BAILEY, L. W. and G. F. MATTHEW. Preliminary report on the geology of southern New Brunswick. Geol. Surv. Canada, Rep. of Prog., 1870–'71, 1872, pp. 13–240.

BILLINGS, E. Note on the discovery of fossils in the "Winooski marble" at Swanton, Vermont. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 145–146. Canadian Naturalist, new ser., vol. 6, p. 351.

——— On some fossils from the Primordial rocks of Newfoundland. Canadian Naturalist, new ser., vol. 6, 1872, pp. 465–479.

——— On some new species of Potsdam fossils. Canadian Naturalist, new ser., vol. 6, 1872, pp. 213–226, 240.

BRADLEY, F. H. On the discovery of the Quebec formation in Idaho. Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 133.

BROOKS, T. B., and R. PUMPELLY. On the age of the copper-bearing rocks of Lake Superior. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 428–432.

DANA, JAMES D. Green Mountain geology. On the quartzite. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 179–186, 250–256.

FORD, S. W. Descriptions of some new species of Primordial fossils. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 419–422.

HUNT, T. S. History of the names Cambrian and Silurian in geology. Canadian Naturalist, new ser., vol. 6, 1872, pp. 281–312, 417–448.

IRVING, R. D. On the age of the quartzites, schists, and conglomerates of Sauk County, Wisconsin. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 93–99. Wisconsin Acad. Sci., Trans., vol. 1, 1872, pp. 129–137.

MEEK, F. B. Report on the paleontology of eastern Nebraska. Final Report U. S. Geological Survey of Nebraska, Washington, 1872, pp. 82–139.

SELWYN, A. R. C. Notes and Observations on the gold fields of Quebec and Nova Scotia. Geol. Surv. Canada, Report Prog. for 1870–71, 1872, pp. 252–282.

WHITNEY, J. D. [On some fossils from Eureka, Nevada.] California Acad. Sci., Proc., vol. 4, 1872, p. 200.

——— Note on the occurrence of the "Primordial fauna" in Nevada. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 84–86.

1873.

BRADLEY, FRANK, H. Report of Frank H. Bradley, geologist of the Snake River Division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, pp. 193–271.

——— Explorations of 1872; U. S. Geological Survey of the Territories, under Dr. F. V. Hayden; Snake River Division. Am. Jour. Sci., 3d ser., vol. 6, 1873, pp. 194–207.

DAWSON, J. W. Impressions and footprints of aquatic animals and imitative markings on Carboniferous rocks. Am. Jour. Sci., 3d ser., vol. 5, 1873, pp. 16–24.
——— Address [On fauna and species in geological time; on the Laurentian and Primordial, and on the so-called glacial period.] Canadian Naturalist, new ser., vol. 7, 1873, pp. 1–11.
FORD, S. W. Remarks on the distribution of the fossils in the Lower Potsdam rocks at Troy, N. Y., with descriptions of a few new species. Am. Jour. Sci., 3d ser., vol 5, 1873, pp. 134–140.
HALL, JAMES. Notes on some new and imperfectly known forms among the Brachiopoda, etc. 23d Ann. Rep. N. Y. State Mus. Nat. Hist., 1873, pp. 244–247.
HALL, JAMES, and R. P. WHITFIELD. Notice of two new species of fossil shells from the Potsdam sandstone of New York. 23d Rept. New York State Mus. Nat. Hist., 1873, pp. 241, 242.
HAYDEN, F. V. Report of F. V. Hayden. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, pp. 12–85.
HITCHCOCK, C. H. The Geology of Portland. Am. Assoc., Proc., vol. 22, part 2, 1873, pp. 163–175.
LESLEY, J. P. The iron ores of the South Mountain along the line of the Harrisburg and Potomac Railway in Cumberland County, Pennsylvania. Am. Phil. Soc., Proc., vol. 13, 1873, pp. 3–21.
MEEK, F. B. Preliminary paleontological report * * * with remarks on the ages of the rocks, etc. U. S. Geol. Survey of the Territories, 6th Ann. Rep., 1873, pp. 429–518.
——— Reports on the Geological Survey of the State of Missouri, 1855–1871, 1873, pp. 111–188.
MURRAY, ALEX. Distribution of the Formations [of Avalon]. Report upon the Geol. Survey of Newfoundland for the year 1872, St. John's, 1873, pp. 14–34. Revised edition, London, 1881, pp. 279–297.
NEWBERRY, J. S. Circles of deposition in American sedimentary rocks. Am. Assoc. Proc., vol. 22, 1873, part 2, pp. 185–196. Canadian Naturalist, new ser., vol. 7, 1873, pp. 163–164.
ROMINGER, C. Paleozoic rocks. Geol. Survey Michigan, Upper Peninsula, 1869–1873, vol. 1, pt. 3, 1873, pp. 1–105.
SEDGWICK, ADAM. [On the classification of the Cambrian rocks.] A Catalogue of the Collection of Cambrian and Silurian Fossils contained in the Geological Museum of the University of Cambridge, by J. W. Salter, 1873, pp. ix–xxxiii.
WINCHELL, N. H. General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey Minnesota, First Ann. Rep. for 1872, 1873, pp. 40–48, 60–118.
——— Preliminary Geological Map of Minnesota, 1872. Geol. and Nat. Hist. Survey Minnesota. First Ann. Rep. for 1872, 1873. Map faces p. 45.

1874.

BRADLEY, FRANK H. Note on the occurrence of metamorphic Silurian rocks in North Carolina. Am. Jour. Sci., 3d ser., vol. 8, 1874, p. 390.
BROADHEAD, G. C. Geological Survey Missouri. Including field work of 1873–74, vol. 1. Jefferson City, 1874, pp. 18–34, 322–370,
BUCKLEY, S. B. First Annual Report of the Geological and Agricultural Survey of Texas. Houston, 1874, pp. 142.
COMSTOCK, T. B. Geological report. Report upon the Reconnaissance of Northwestern Wyoming, made in the summer of 1873, by William A. Jones, 1874, pp. 85–184, with a colored geological map.
COOK, GEO. H. Geological Survey of New Jersey. Map of northern New Jersey, showing the iron ore and limestone districts, 1874.
DANA, JAMES D. Reasons for some of the changes in the subdivisions of geological time in the new edition of Dana's Manual of Geology. Am. Jour. Sci., 3d ser., vol. 8, 1874, pp. 213–216.
GILBERT, G. K. On the age of the Tonto sandstone. (Abstract.) Washington Phil. Soc. Bull., vol. 1, 1874, p. 109.
HAYDEN, F. V. Report of F. V. Hayden, U. S. Geologist. U. S. Geol. Surv. of the Terr., Seventh Ann. Rep, 1874, pp. 17–82.
HITCHCOCK, C. H. Physical history of New Hampshire. Geology of New Hampshire, Concord, 1874, vol. 1, pp. 506–545.
——— History of the geological surveys of New Hampshire. Geology of New Hampshire, vol. 1, 1874, pp. 3–58.
IRVING, R. D. On the age of the copper-bearing rocks of Lake Superior; and on the westward continuation of the Lake Superior synclinal. Am. Jour. Sci., 3d ser., vol. 8, 1874, pp. 46–56.

IRVING, R. D. On some points in the geology of northern Wisconsin. Wisconsin Acad. Sci., Trans., vol. 2, 1874, pp. 107–119.
JENNEY, W. P. (Recent explorations in the geology of Western Texas.) New York Lyceum Nat. Hist., Proc., vol. 2, 1874, pp. 68, 69.
KILLEBREW, J. B. Resources of Tennessee. Nashville, 1874, pp. 26–46.
NEWBERRY, J. S. Remarks on geology of Western Texas. New York Lyceum Nat. Hist., Proc., vol. 2, 1874, pp. 69, 70.
PEALE, A. C. Report of A. C. Peale, M. D., geologist of the South Park Division. U. S. Geol. Surv. of the Terr., Seventh Ann. Rep., 1874, pp. 193–273.
WHITE, C. A. Preliminary report upon invertebrate fossils collected by the expeditions of 1871, 1872, and 1873, with descriptions of new species. Geog. and Geol. Sur. West of 100th Mer., Lieut. Wheeler in charge, Washington, 1874, pp. 27.
WINCHELL, N. H. The geology of the Minnesota Valley. Geol. and Nat. Hist. Sur. Minn., Second Ann. Rep. for 1873, 1874, pp. 127–212.

1875.

BRADLEY, FRANK H. On the Silurian age of the southern Appalachians. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 279–288, 370–383.
DODGE, W. W. Notes on the geology of eastern Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 17, 1875, pp. 388–419.
FONTAINE, WILLIAM M. On the primordial strata of Virginia. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 361–369, 416–428.
FORD, S. W. Note on the discovery of a new locality of primordial fossils in Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 204–206.
GILBERT, G. K. Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Geog. and Geol. Expl. and Surv. West of the 100th Mer., Lieut. Geo. M. Wheeler in charge, vol. 3, Geology, 1875, pp. 17–187.
——— Report on the geology of portions of New Mexico and Arizona examined in 1873. Geog. and Geol. Expl. and Surv. West of the 100th Mer., Lieut. G. M. Wheeler in charge, vol. 3, 1875, pp. 503–567.
HAYDEN, F. V. Catalogue of the collections in geology and natural history obtained by the expedition under command of Lieut. G. K. Warren. Appx. to Rept. Sec. of War, in Rept. of Topog. Eng., for 1858 (reprint edition of 1875, pp. 59–125, map).
HICKS, HENRY. The physical conditions under which the Cambrian and Lower Silurian rocks were probably deposited over the European area. Quart. Jour. Geol. Soc. London, vol. 31, 1875, pp. 552–558.
HITCHCOCK, C. H. Remarks on the stratigraphic structure of the Cambrian and Cambro-Silurian rocks of western Vermont. Boston Soc. Nat. Hist., Proc., vol. 18, 1875, pp. 191–193.
HOWELL, EDWIN E. Report on the geology of portions of Utah, Nevada, Arizona, and New Mexico examined in the years of 1872 and 1873. Geog. and Geol. Expl. and Sur. West of the 100th Mer., Lieut. Geo. M. Wheeler in charge, vol. 3, Geology, 1875, pp. 227–301.
HUNT, T. STERRY. (Remarks on Massachusetts geology.) Boston Soc. Nat. Hist., Proc., vol. 17, 1875, pp. 509, 510.
IRVING, ROLAND D. Note on some new points in the elementary stratification of Primordial and Canadian rocks of south-central Wisconsin. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 440, 443.
KERR, W. C. Report of the geological survey of North Carolina, vol. 1. Raleigh, 1875, pp. xviii, 325.
MARVINE, A. R. Report on the geology of route from St. George, Utah, to Gila River. Arizona, examined in 1871. Geog. and Geol. Expl. and Sur. West of 100th Mer., Lieut. Geo. M. Wheeler in charge, vol. 3, Geology, 1875, pp. 189–225.
POWELL, J. W. Exploration of the Colorado River of the West and its tributaries, explored in 1869, 1870, 1871, and 1872. Washington, 1875, pp. 214.
ROGERS, W. B. On the Newport conglomerate. Boston Soc. Nat. Hist., Proc., vol. 18, 1875, pp. 97–101.
SMITH, E. A. Geological Survey of Alabama. Report of progress for 1874. Montgomery, Alabama, 1875, pp. 139.
WHITE, C. A. Report upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona by parties of the expeditions of 1871–'74. Expl. and Surv. West of the 100th Mer., Lieut. Geo. M. Wheeler, in charge, vol. 4, pt. i, 1875, pp. 219.

1876.

BUCKLEY, S. B. Second Annual Report of the Geological and Agricultural Survey of Texas. Houston, 1876, pp. 96.

CROSBY, W. O. Report on the Geological Map of Massachusetts. Boston, 1876, pp. 42.

DANA, EDW. S., and G. B. GRINNELL. Geological report. Report of a geological reconnoissance from Carroll, Montana Territory, on the upper Missouri, to the Yellowstone Park and return, made in the summer of 1875, under Wm. Ludlow, 1876, pp. 93–137.

FORD, S. W. On additional species of fossils from the Primordial of Troy and Lansingburgh, Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 11, 1876, pp. 369–371.

HUNT, T. STERRY. On the history of the crystalline stratified rocks. Am. Assoc. Proc., vol. 25, 1876, pp. 205–208.

——— The Cornwall iron mine and some related deposits in Pennsylvania. Am. Inst. Mining Eng., Trans., vol. 4, 1876, pp. 319–324.

KAYSER, EMANUEL. Ueber primordiale und untersilurische Fossilien aus der Argentinischen Republik. Beiträge zur Geologie und Palaeontologie der Argentinischen Republik; part II, Palaeontologischer Theil, I Abtheilung, 1876, pp. 33.

KING, CLARENCE. Paleozoic subdivisions on the Fortieth parallel. Am. Jour. Sci., 3d ser., vol. 11, 1876, pp. 475–482.

LITTLE, GEORGE. Geological Survey of the State of Georgia. Hand-book of the State of Georgia, with geologic map of the State, by T. P. Janes, 1876, pp. 17–61.

LLOYD, T. G. B. Geological notes from the State of New York. Quart. Jour. Geol. Soc., London, 1876, vol. 32, pp. 76–79.

PEALE, A. C. [Report on Middle Division.] Stratigraphy—Paleozoic formations. U. S. Geol. and Geog. Surv. of the Territories. Ann. Rep. for 1874, 1876, pp. 110–120.

POWELL, J. W. Report on the Geology of the Eastern Portion of the Uinta Mountains and a Region of Country Adjacent Thereto. Washington, 1876, pp. 3–73, 136–210.

SMITH, EUGENE A. Report of Progress of the Geological Survey of Alabama for 1875. Montgomery, 1876, pp. 220.

SWEET, E. T. Notes on the geology of northern Wisconsin. Wisconsin Acad. Sci., Trans., vol. 3, 1876, pp. 40–55.

WHITE, CHARLES A. Invertebrate paleontology of the plateau province, together with notice of a few species from localities beyond its limits in Colorado. Report on the geology of the eastern portion of the Uinta Mountains, by J. W. Powell. Washington, 1876, pp. 74–135.

WHITFIELD, R. P. Descriptions of new species of fossils. Report of a reconnoissance from Carroll, Montana Territory, on the Upper Missouri, to the Yellowstone Park and return, made in the summer of 1875, under William Ludlow, 1876, pp. 139–145.

——— Description of new fossils. Report of Geol. Recon. of Black Hills. Appx. PP. of report of Chief of Engineers, 1876, pp. 1202, 1203.

WINCHELL, N. H. Notes on the deep well drilled at East Minneapolis, Minnesota, in 1874–'75. Minnesota Acad. Sci. Bull., vol. 1, 1876, pp. 187–189.

——— Report on the geology of Fillmore County. Geol. and Nat. Hist. Survey Minnesota; 4th Ann. Rep., for 1875, 1876, pp. 13–74, map.

——— Geological report [of a reconnaissance of the Black Hills of Dakota, made in the summer of 1874, by Capt. William Ludlow]. Report of the Chief of Engineers, Appx. PP, 1876, pp. 1131–1172.

1877.

BROADHEAD, G. C. The southeastern Missouri lead district. Am. Inst. Mining Eng. Trans., vol. 5, 1877, pp. 100–107.

CHAMBERLIN, T. C. [Geology of eastern Wisconsin.] Chapters 7 and 8, Lower and Upper Silurian. Geology of Wisconsin, Survey of 1873–'77, vol. 2, 1877, pp. 257–394.

CHAPMAN, E. J. On the probable nature of the supposed fossil tracks known as Protichnites and Climactichnites. Canadian Journal, new ser., vol. 15, 1877, pp. 486–490.

DANA, JAMES D. An account of the discoveries in Vermont geology of the Rev. Augustus Wing. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 332–347, 405–419; vol. 14, 1877, pp. 36–37.

FLETCHER, HUGH. Report of explorations and surveys in Cape Breton, Nova Scotia *Geol. Surv. Canada*, Rep. Progress for 1875–'76, 1877, pp. 369–418.

FORD, S. W. Note on Microdiscus speciosus. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 141, 142.
——— On some embryonic forms of trilobites from the Primordial at Troy, New York. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 265–273.
HAGUE, ARNOLD, and S. F. EMMONS. Descriptive geology. U. S. Geol. Expl. of the Fortieth Par. under Clarence King, vol. 2. 1877, pp. 890.
HALL, JAMES, and R. P. WHITFIELD. Paleontology [of the 40th parallel]. General remarks. U. S. Geol. Survey of the 40th parallel, vol. 4, 1877, pp. 199–302.
HITCHCOCK, C. H. Geology of New Hampshire, Concord, 1877, vol. 2, pp. 3–36.
——— Geological map of New Hampshire and Vermont, with notes on topography and geology. In Geology of Northern New England, 1877, pp. 17.
IRVING, ROLAND D. The Lower Silurian rocks. (Geology of central Wisconsin.) Geology of Wisconsin, Survey of 1873–1877, vol. 2, 1877, pp. 525–607.
——— Note on the age of the crystalline rocks of Wisconsin. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 307–309.
MEEK, F. B. Paleontology. Report of the Geol. Sur. of the Fortieth Parallel, vol. 4, 1877 pp. 197.
MILNE, JOHN, and ALEXANDER MURRAY. On the rocks of Newfoundland. Geological Magazine, vol. 4, new ser., decade II, 1877, pp. 251–262.
STRONG, MOSES. Geological formations. [Geology and topography of the lead regions.] Geology of Wisconsin, Survey of 1873–'77, vol. 2, 1877, pp. 668–688.
WHITFIELD, R. P. Preliminary report on the paleontology of the Black Hills. U. S. Geol. and Geog. Surv. of the Rocky Mountain Region, 1877, pp. 49.

1878.

DAWSON, J. W. Supplement to the second edition of Acadian Geology, containing additional facts as to the geological structure, fossil remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, London, 1878, pp. 102.
ENDLICH, F. M. Report of F. M. Endlich, geologist of the White River division. U. S. Geol. Surv. of the Terr., 10th Ann. Rep., 1878, pp. 61–131.
FLETCHER, HUGH. Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Surv. Canada, Rep. progress for 1876–'77. Montreal, 1878, pp. 402–456.
FORD, S. W. On certain forms of Brachiopoda occurring in the Swedish Primordial. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 364–366.
——— Note on the development of Olenellus asaphoides. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 129, 130.
——— Note on Lingulella coelata. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 127–129.
——— Two new species of Primordial fossils. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 124–127.
FRAZER, PERSIFOR, jr. (Note on the Martic anticlinal and on ripple marks on a slab of limestone.) Am. Phil. Soc., Proc., vol. 17, 1878, p. 725.
HUNT, T. S. Special report on the trap dikes and Azoic rocks of southern Pennsylvania. 2d Geol. Surv. Pa., E., 1878, pp. 253.
——— On the geology of the Eozoic rocks of North America. (Abstract.) Boston Soc. Nat. Hist., Proc., vol. 19, 1878, pp. 275–279.
KING, CLARENCE. Systematic geology. U. S. Geol. Exploration of the Fortieth Parallel, Clarence King, geologist in charge, vol. 1, 1878, pp. xii, 803.
MATTHEW, G. F. Report on the slate formations of the northern part of Charlotte County, New Brunswick. Geol. Surv. Canada, Rep. progress for 1876–'77. Montreal, 1878, pp. 321–350.
PRIME, FREDERICK, Jr. On the Paleozoic rocks of Lehigh and Northampton Counties, Pennsylvania. Am. Phil. Soc., Proc., vol. 17, 1878, pp. 248–254.
——— *Monocraterion lesleyi*, n. sp. Appendix to report on the Brown hematite deposits of the Siluro-Cambrian limestones of Lehigh County. 2d Geol. Surv. Penn., DD, 1878, pp. 79, 80.
——— On the discovery of Lower Silurian fossils in limestone associated with hydromica slates in eastern Pennsylvania. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 261–269.
SMITH, EUGENE A. Outline of the geology of Alabama. Berney's Hand-book of Alabama, 1878, pp. 129–196.
——— The iron ores of Alabama, with special reference to their geological relations. Am. Assoc., Proc., vol. 27, 1878, pp. 246–258.
WHITEAVES, J. F. On some Primordial fossils from southeastern Newfoundland. Am. Jour. Sci., 3d. ser., vol. 16, 1878, pp. 224–226.
WHITFIELD, R. P. Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin. Geol. Sur. of Wisconsin, Ann. Rep. for 1877, 1878, pp. 50–89.

WINCHELL, N. H. The geology of Rock and Pipestone Counties. Geol. and Nat. Hist. Survey Minnesota, 6th Ann. Rep. for 1877, 1878, pp. 93–111.
WOOSTER, L. C. Work in St. Croix, Dunn, and adjacent counties. Geol. Survey Wisconsin, Ann. Rep. for 1877, 1878, pp. 36–41.

1879.

BAILEY, L. W. Report on the pre-Silurian (Huronian) and Cambrian or Primordial Silurian rocks of southern New Brunswick. Geol. Surv. Canada, Rep. of Prog., 1877–'78, 1879, pp. 34 DD.
BELL, ROBERT. Report on an exploration of the east coast of Hudson's Bay, 1877. Geol. Surv. Canada, Rep. Prog. for 1877–'78, 1879, pp. 37C.
CAMPBELL, J. L. Silurian formation in Central Virginia. Am. Jour. Sci., 3d ser. vol. 18, 1879, pp. 16–29. Geology of Virginia. Balcony Falls. The Blue Ridge and its geological connections. Some theoretical considerations. Am. Jour. Sci., 3d ser, vol. 18, 1879, pp. 435–445.
ENDLICH, F. M. Report on the geology of the Sweetwater district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 3–156.
(FRAZER, PERSIFOR.) [On the relations of the South Mountain rocks in Pennsylvania.] Am. Inst. Mining Eng. Trans., vol. 7, 1879, pp. 336–339.
HITCHCOCK, C. H. Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, pp. 56–66.
HUNT, T. S. Dominion of Canada. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, pp. 52–55.
PEALE, A. C. Report on the geology of the Green River district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 509–644.
ROGERS, WILLIAM B. Virginia and West Virginia. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, pp. 179–185. Table of the geological formations found in Virginia and West Virginia. The Virginias, vol. 1, 1880, pp. 14, 15; vol. 3, 1882, pp. 61.
SAFFORD, JAMES M. Tennessee. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, pp. 196–199.
SELWYN, A. R. C. Report of observations on the stratigraphy of the Quebec group and the older crystalline rocks of Canada. Geol. Surv. Canada, Rep. of Prog. 1877–'78, pp. 15A. Canadian Naturalist, new ser., vol. 9, 1879, pp. 17–31.
ST. JOHN, ORESTES. Report of the geological field work of the Teton division. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 321–508.
WALCOTT, C. D. Descriptions of new species of fossils from the Calciferous formation. 32d Rep. State Mus. Nat. Hist. N. Y., 1879, pp. 129–131.
WHITE, C. A. Report on the paleontological field work for the season of 1877. 11th Ann. Rep. U. S. Geol. Surv. of the Territories for 1877, 1879, pp. 251–265. (General discussion.)

1880.

BAILEY, L. W., G. F. MATTHEW, and R. W. ELLS. Report on the geology of southern New Brunswick embracing the counties of Charlotte, Sunbury, Queens, Kings, St. John, and Albert. Geol. Survey Canada, Rep. of Prog., 1878–'79, 1880, pp. 26D.
CAMPBELL, J. L. The Silurian formation in Central Virginia. (Revised.) The Virginias, vol. 1, 1880, pp. 41–45, 54–56.
——— The mineral resources and advantages of the country adjacent to the James River and Kanawha Canal and the Buchanan and Clifton Forge Railway. The Virginias, vol. 1, 1880, pp. 2–8.
CROSBY, W. O. Contributions to the geology of eastern Massachusetts. Boston Soc. Nat. Hist., occasional papers, No. 3, 1880, pp. 286.
FORD, S. W. Note on the trilobite, Atops trilineatus of Emmons. Am. Jour. Sci., 3d ser., vol. 19, 1880, pp. 152, 153.
FRAZER, PERSIFOR, Jr. The geology of Lancaster County. Second Geol. Survey Penn., Rep. progress in 1877, CCC. Harrisburg, 1880, pp. x, 350.
IRVING, R. D. The mineral resources of Wisconsin. Am. Inst. Mining Eng. Trans., vol. 8, 1880, pp. 478–508.
——— The Lake Superior or Potsdam sandstone. [Geology of the eastern Lake Superior district.] Geol. of Wisconsin, vol. 3, 1880, pp. 207–210.
——— Geological structure of Northern Wisconsin. [General geology of the Lake Superior region.] Geol. of Wisconsin, vol. 3, 1880, pp. 1–25.
MARCOU, JULES. Sur les colonies dans les roches taconiques des bords du lac Champlain. Soc. géol., France, Bull., 3e sér., vol. 9, 1880, pp. 18–46.

MARR, J. E. On the pre-Devonian rocks of Bohemia. Quart. Jour. Geol. Soc. London, vol. 36, 1880, pp. 591–619.
NEWTON, HENRY. Geology. Section IV. The Silurian. The Potsdam sandstone. U. S. Geog. and Geol. Survey of the Rocky Mountain region, J. W. Powell in charge: Report on the Black Hills of Dakota. 1880, pp. 80–107.
STRONG, MOSES. Geology of the upper St. Croix district. Geology of Wisconsin, survey of 1873–1879, vol. 3, 1880, pp. 390–428.
SWEET, E. T. Lake Superior sandstone. [Geology of the Western Lake Superior District.] Geology of Wisconsin, survey of 1873–1879, vol. 3, 1880, pp. 350–352.
WADSWORTH, M. E. Notes on the geology of the iron and copper district of Lake Superior. Cambridge Mus. Comp. Zool. Bull., vol 7, 1880, pp. 157.
WALCOTT, C. D. The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 221–224.
WHITE, C. A. Note on Acrothele. U. S. Nat. Mus. Proc., vol. 3, 1880, p. 47.
WHITFIELD, R. P. Paleontology of the Black Hills of Dakota. Report on the geology and resources of the Black Hills of Dakota, 1880, pp. 325–468.
WINCHELL, N. H. Section of a deep well at Emmetsburgh, Iowa. Minn. Acad. Sci. Bull., vol. 1, 1880, pp. 387, 388.

1881.

CROSBY, W. O. Geology of Frenchman's Bay. Boston Soc. Nat. Hist., Proc. vol. 21, 1881, pp. 109–117. Geology of Frenchman's Bay, Maine, just east of Mt. Desert Island. Am. Jour. Sci., 3d ser., vol. 23, 1882, p. 64.
DUTTON, CLARENCE E. The physical geology of the Grand Cañon District. U. S. Geol. Survey, 2d Ann. Rep. 1880–'81, 1881, pp. 47–166.
FORD, S. W. Remarks on the genus Obolella. Am. Jour Sci., 3d ser., vol. 21, 1881, pp. 131–134.
——— Embryonic forms of trilobites from the Primordial rocks of Troy, N. Y. Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 250–259.
HAGUE, ARNOLD. Report [on work in Eureka District]. U. S. Geol. Survey, 2d Ann. Rep., 1880–'81, 1881, pp. 21–35.
HALL, CHARLES E. The geology of Philadelphia County and of the southern parts of Montgomery and Bucks. 2d Geol. Survey Pa., C6, 1881 pp. XVII, XVIII, 93.
LAPWORTH, CHAS. Materials for the correlation of the Lower Palæozoic rocks of Britain and Scandanavia. Geological Magazine, new ser., decade II, vol. 8, 1881, pp. 260–266, 317–322.

1882.

BROADHEAD, G. C. Marble of southeast Missouri. Kansas City Review, vol. 5, 1882, pp. 523–526.
FRAZER, PERSIFOR. Mémoire sur la Géologie de la parte sud-est de la Pennsylvanie. Lille, 1882, pp. 179.
GEIKIE, ARCHIBALD. Text Book of Geology. London, 1882, pp. xi, 971.
HAGUE, ARNOLD. Abstract of report on geology of the Eureka district, Nevada. U. S. Geol. Survey, 3d Annual Report, 1881–1882, 1882, pp. 237–290.
KLOOS, J. H. Geological notes on Minnesota. (Translated by N. H. Winchell.) Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, pp. 175–200.
RICHTOFEN, F. F. von. Geologische Beobachtungen am Reiseweg durch die südliche Mantschurei. Drittes Capitel, in "China, Ergebnisse Reisen und darauf gegrundeter Studien," vol. 2, 1882, pp. 69–124.
STRONG, MOSES. Geological formations. [Geology of the Mississippi region north of the Wisconsin River.] Geology of Wisconsin, Survey of 1873–1879, vol. 4, 1882, pp. 38–91.
TODD, JAMES E. A description of some fossil tracks from the Potsdam sandstone. Wisconsin Acad. Sci., Trans., vol 5, 1882, pp. 276–281.
WADSWORTH, M. E. On the relation of the Quincy granite to the primordial argillite of Braintree, Massachusetts. Boston Soc. Nat., Hist. Proc., vol. 21, 1882, pp. 274–277.
WHITFIELD, R. P. Paleontology [of Wisconsin]. Geology of Wisconsin, vol. 4, 1882, pp. 163–363.
WINCHELL, N. H. The Potsdam Sandstone. Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, pp. 123–136.
——— The geology of the deep well drilled by C. C. Whelpley at Minneapolis, at the "C" Washburn Mill. Geol. and Nat. Hist., Survey Minnesota, 10th Ann. Rep. for 1881, 1882, pp. 211–217.
WOOSTER, L. C. Detailed Geology. [Geology of the lower St. Croix district.] Geology of Wisconsin, Survey of 1873–1879, vol. 4, 1882, pp. 109–130.
YOUNG, A. A. Further observations on the crystallized sands of the Potsdam sandstone of Wisconsin. Am. Jour. Sci., 3d ser., vol. 24, 1882, pp. 47–49.

1883.

CAMPBELL, J. L., and W. H. RUFFNER. A Physical Survey extending from Atlanta, Georgia, across Alabama and Mississippi to the Mississippi River, along the line of the Georgia Pacific Railway. New York, 1883, pp. 3–117.

CHAMBERLIN, T. C. General geology. Historical geology. Palæozoic era. Geol. Wisconsin, Survey of 1873–1879, vol. 1, 1883, pp. 119–200.

——— The copper-bearing series of Lake Superior. Science, vol. 1, 1883, pp. 453–455.

DAMES, WILHELM. Cambrische trilobiten von Lian-Tung. In China, by F. F. von Richtofen, vol. 4, 1883, pp. 1–36, pls. 1 and 2.

D(AWSON), J. W. Impressions on Potsdam sandstone. Science, vol. 1, 1883, p. 177.

D'INVILLIERS, E. The Geology of the South Mountain Belt of Berks County, 2d Geol. Sur. of Penna. D3, vol. 2, part 1, 1883, pp. xxii–441.

ELLIOTT, JOHN B. The age of the Southern Appalachians. Am. Jour. Sci., 3d ser., vol. 25, 1883, pp. 282–298.

ETHERIDGE, R., Jr. Trilobites and other fossils from the Mersey River district. Papers and Proc. Roy. Soc. Tasmania for 1882–1883, pp. 151–158.

FERRIER, W. F. Notes on a fossil track from the Potsdam sandstone of northern New York State. Canadian Naturalist, new ser., vol. 10, 1883, pp. 466, 467.

FONTAINE, W. M. Notes on the mineral deposits at certain localities on the western part of the Blue Ridge. The Virginias, vol. 4, 1883, pp. 21, 22, 42–47, 55–59, 73–76, 92, 93.

——— [Letter on relations of Archæan and associated formations in Virginia.] Geol. Chester Co., Pa. 2d Geol. Surv. Pa., C4. 1883, pp. xiii–xvi.

FRAZER, PERSIFOR. Geological notes on the several townships of Chester County. 2d Geological Sur. Penn. The Geol. of Chester County, C4, 1883, pp. 215–345.

HATTON, JOSEPH, and M. HARVEY. Geology of Newfoundland. Newfoundland, the oldest British Colony, its history, its present condition, and its prospects in the future. London, 1883, pp. 176–187. Boston, 1883, pp. 150–157.

HUNT, T. STERRY. The Geology of Lake Superior. Science, vol. 1, 1883, pp. 218, 219.

——— The geology of Port Henry, New York. Canadian Naturalist, new ser., vol. 10, 1883, pp. 420–422.

IRVING, R. D. The copper-bearing rocks of Lake Superior. U. S. Geol. Survey, Monographs, vol. 5, 1883, pp. xvi, 464. U. S. Geol. Survey, 3rd Ann. Rep., 1881–'82, 1883, pp. 89–188.

——— The copper-bearing rocks of Lake Superior. Science, vol. 1, 1883, pp. 140, 141, 359, 360, 422.

LESLEY, J. PETER. The Geology of Chester County after the surveys of Rogers, Frazer, and Hall. (With plate and map.) 2d Geol. Surv. Penn. CCCC, 1883, pp. i–xx, 1–54, 63–213, 351–354.

LEWIS, H. CARVILL. The Geology of Philadelphia. Franklin Institute Jour., 3d ser., vol. 85, 1883, pp. 359–374, 422–427.

MARR, JOHN E. The classification of the Cambrian and Silurian rocks. The Sedgwick Prize Essay for the year 1882. Cambridge and London, 1883, pp. xxiv, 147.

MATTHEW, G. F. Illustrations of the fauna of the St. John group. Royal Soc. Canada, Proc. and Trans., vol. 1, 1883, section IV, pp. 87–108, pp. 271–279.

PRIME, FREDERICK, Jr. Geology of Lehigh and Northampton Counties. 2d Geol. Surv. Pa., D3, vol. 1, 1883, pp. 161–212, 2 maps.

SELWYN, A. R. C. Age of the rocks on the northern shore of Lake Superior. Science, vol. 1, 1883, pp. 11, 221.

——— Notes on the geology of the southeastern portion of the Province of Quebec. Geol. Surv. Canada, Rep. Prog., for 1880, '81–'82, 1883, pp. 1A–7A.

SMITH, EUGENE A. Geological features and divisions of Alabama. Geol. Surv. Alabama, Rept. for 1881 and 1882, 1883, pp. 178–181, 192–210.

ST. JOHN, ORESTES. Report on the geology of the Wind River district. U. S. Geol. Surv. of the Terr., 12th Ann. Rep., 1883, pp. 173–269.

WADSWORTH, M. E. The Argillite and conglomerate of the Boston Basin. Boston Soc. Nat. Hist., Proc., vol. 22, 1883, pp. 130–133.

WALCOTT, C. D. The Cambrian system in the United States and Canada. Washington Phil. Soc., Bull., vol. 6, 1883, pp. 98–102.

——— Pre-Carboniferous Strata in the Grand Cañon of the Colorado, Arizona. Am. Jour. Sci., 3d ser., vol. 26, 1883, pp. 437–442, 484.

WHITNEY, J. D. Geology of Lake Superior. Science, vol. 1, 1883, p. 39.

WINCHELL, N. H. The Lake Superior rocks. Science, vol, 1, 1883, p. 334.

1884.

CAMPBELL, J. L. Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view. Am. Jour. Sci., 3d ser., 1884, vol. 28, pp. 221–223. The Virginias, vol. 5, 1884, p. 145.

CAMPBELL, J. L. and H. D. The Snowdon slate quarries. The Virginias, vol. 5, 1884, pp. 162, 163, 170.

CHESTER, FREDERICK D. Preliminary notes on the geology of Delaware. Laurentian, Paleozoic, and Cretaceous areas. Phila. Acad. Sci., Proc., vol. 36, 1884, pp. 237–259.

COOK, GEO. H. Geological Survey of New Jersey. Annual report of the State Geologist for the year 1884, 1884, pp. 168, map and 4 pls.

DAWSON, GEORGE M. Recent geological observations in the Canadian Northwest Territory. Science, vol. 3, 1884, pp. 647, 648.

FORD, S. W. On the age of the glazed and contorted slaty rocks in the vicinity of Schodack Landing, Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 206–208.

——— Note on the discovery of primordial fossils in the town of Stuyvesant, Columbia County, New York. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 35–37.

HALL, JAMES. Cryptozoon, n. g., Cryptozoon proliferum, n. sp. 36th Ann. Rep. State Mus. Nat. Hist, 1884, Pl. VI.

HITCHCOCK, C. H. Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, pp. 155–179, plates 16–18. On thirteen sections across Vermont and New Hampshire. Science, vol. 4, 1884, p. 327.

LOW, A. P. Explorations and Surveys in the interior of the Gaspé Peninsula, 1883. Geol. Survey Canada, 1882-3-4, 1884, pp. 21F.

MCCREATH, ANDREW. The Iron Ores of the Valley of Virginia. Am. Inst. Mining Eng. Trans., vol. 12, 1884, pp. 17–26.

MCCUTCHEN, A. R. Northwest Georgia. (Geologic description.) Tenth Census U. S., vol. 6; Report on Cotton Production in the United States, pt. 2, 1884, pp. 285–295.

MATTHEW, G. F. The geologic age of the Acadian fauna. The primitive Conocoryphean. British Assoc. Rep. 54th meeting, 1884, pp. 742, 743. The geologic age of the Acadian fauna. Geol. Mag., new ser., decade 3, vol. 1, 1884, pp. 470, 471.

ROGERS, WM. B. A reprint of annual reports and other papers on the Geology of the Virginias. New York, 1884, pp. xv, 832, with map and colored sections.

SMITH, E. A. General description of the State of Alabama. Tenth Census U. S., vol. 6; Report on Cotton Production in the United States, pt. 2, 1884, pp. 19–69 (bottom pagination), map.

UPHAM, WARREN. The Geology of Minnesota. Vol. 1 of Final Report, 1884, pp. 404–532, 562–588, 632–647.

WADSWORTH, M. E. On the relation of the "Keweenawan Series" to the Eastern sandstone in the vicinity of Torch Lake, Michigan. Boston Soc. Nat. Hist., Proc., vol. 23, 1884, pp. 172–180.

WALCOTT, C. D. Paleontology of the Eureka District. U. S. Geol. Surv. Monograph, vol. 8, 1884, pp. 298.

——— On the Cambrian faunas of North America; preliminary studies. U. S. Geol. Survey Bull. No. 10; vol. 2, 1884, pp. 283–354. Separately paged, 1–74.

——— Notes on Paleozoic rocks of Central Texas. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 431–433.

——— Potsdam fauna at Saratoga, New York. Science, vol. 3, 1884, pp. 136, 137.

WHITFIELD, R. P. Notice of some new species of Primordial fossils in the collections of the Museum and correction of previously described species. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, pp. 139–154.

WHITNEY, J. D., and M. E. WADSWORTH. The Azoic system and its proposed subdivisions. Harvard Mus. Comp. Zool., Bull., vol. 7, 1884, pp. 331–565.

WINCHELL, N. H. Notes on the age of the rocks of the Mesabi and Vermilion iron districts. Geol. and Nat. Hist., Survey Minnesota, 11th Ann. Rep. for 1883, 1884, pp. 168–170.

——— The geology of Minnesota. Vol. 1 of the Final Report, 1884, pp. 1–324, 347–366, 376–393, 533–561, 648–673.

WOODWARD, HENRY. Notes on the remains of Trilobites from South Australia. Geol. Magazine, n. ser., dec. III, vol. 1, 1884, pp. 342–344.

WOOSTER, L. C. Transition from the copper-bearing series to the Potsdam. Am. Jour. Sci., 3d ser., vol. 27, 1884, pp. 463–465.

1885.

CAMPBELL, H. D. The Potsdam group east of the Blue Ridge at Balcony Falls, Virginia. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 470–474.

CAMPBELL, J. L., and H. D. CAMPBELL. Review of William B. Rogers's Geology of the Virginias. Am. Jour. Sci., 3d ser., vol. 30, 1885, pp. 357–374; vol. 31, pp. 193–202.

COOK, G. H. Contact phenomena with the Paleozoic rocks. Geol. Surv. of New Jersey. Ann. Rep. State Geologist for 1885. Trenton, 1885, pp. 53–55.

DANA, JAMES D. On Taconic rocks and stratigraphy, with a geological map of the Taconic region. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 205–222, 437–443.

HALL, CHARLES E. Laurentian magnetic iron-ore deposits from northern New York, accompanied by a geological map of Essex County. Report of the State Geologist for the year 1884. Albany, 1885, pp. 23–34; map op. p. 23.

HAYDEN, F. V. (Report of the Montana division.) U. S. Geol. Survey, 6th Ann. Rep., 1884–'85, 1885, pp. 48–53.

HENDERSON, J. T. Geology [of Georgia]. The Commonwealth of Georgia. The Country; the People; the Productions. Atlanta, 1885, pp. 74–117.

HITCHCOCK, C. H. Geological map of Maine (with notes on geology of). In Geology of North England, 1885, pp. 4.

HYATT, ALPHEUS. Expedition to Newfoundland. Boston Soc. Nat. Hist., Proc., vol. 23, 1886, pp. 316–319. Cruise of the *Arethusa*. Science, vol. 6, 1885, pp. 384–386.

IRVING, R. D. Preliminary paper on an investigation of the Archean formations of the Northwestern States. U. S. Geol. Survey, 5th Ann. Rep. 1883–84, 1885, pp. 175–242.

IRVING, R. D., and T. C. CHAMBERLIN. Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior. U. S. Geol. Sur. Bull. No. 23, 1885, pp. 124.

LESLEY, J. P. A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the field work of the survey from 1874 to 1884. 2d Geol. Surv. Penn., X, 1885, pp. cxii.

MARCOU, JULES. The "Taconic System" and its position in stratigraphic geology. Am. Acad. Proc., vol. 20, 1885, pp. 174–256.

MATTHEW, G. F. An outline of recent discoveries in the St. John group. New Brunswick Nat. Hist. Soc., Bull. No. 4, 1885, pp. 97–102.

——— Illustrations of the fauna of the St. John group, continued; on the Conocoryphea, with further remarks on Paradoxides. Royal Soc. Canada, Trans. and Proc., vol. 2, sec. iv, 1885, pp. 99–124.

PERKINS, GEO. H. The Winooski or Wakefield marble of Vermont. Am. Naturalist, vol. 19, 1885, pp. 128–136.

UPHAM, WARREN. Notes on the geology of Minnehaha County, Dakota. Geol. and Nat. Hist. Survey Minnesota, 13th Ann. Rep. for 1884, 1885, pp. 88–97.

WALCOTT, C. D. Paleontologic Notes. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 114–117.

——— Paleozoic notes; new genus of Cambrian trilobites, Mesonacis. Am. Jour. Sci., 3d ser., vol. 28, 1885, pp. 328–331.

WINCHELL, N. H. Fossils from the red quartzite at Pipestone. Geol. and Nat Hist. Surv. Minn., 13th Ann. Rep. for 1884, 1885, pp. 65–72.

WINWOOD, H. H. Geological age of the Rocky Mountains. Geol. Magazine, new ser., dec. III, vol. 2, 1885, p. 240.

1886.

BEECHER, C. E., and C. E. HALL. Field notes on the geology of the Mohawk Valley. 5th Ann. Rep. of Geologist of New York for 1885, 1886, pp. 8–10, map.

BRÖGGER, W. C. Om alderen af Olenelluszonen i Nordamerica. (On the age of the Olenellus zone in North America.) Aftryck ur Geol. Fören. i Stockh. Förhan, No. 101, Bd. 8, 1886, pp. 182–213.

DAWSON, GEO. M. Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30′. Geol. Survey Canada, new ser., vol. 1, 1886, pp. 169B.

DWIGHT, WILLIAM B. Discovery of fossiliferous Potsdam strata at Poughkeepsie, New York. Am. Assoc., Proc., vol. 34, 1886, pp. 204–209.

——— Recent explorations in the Wappinger Valley limestone of Dutchess County, New York. No. 5: Discovery of fossiliferous Potsdam strata at Poughkeepsie, New York. (Illustrated by map, Plate VI.) Am. Jour. Sci., 3d ser. vol. 31, 1886, pp. 125–133. Primordial Rocks of the Wappinger Valley Limestone. *Vassar* Brothers Inst. Trans., vol. 4, 1887, pp. 130–141.

EMMONS, S. F. Geology and mining industry of Leadville, Colorado. Monographs *of U. S.* Geol. Survey, vol. 12, part 1, 1886, pp. 362.

FORD, S. W. Note on the age of the Swedish Paradoxides beds. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 473–476.
FRAZER, PERSIFOR. General notes. Sketch on the geology of York County, Pennsylvania. Am. Phil. Soc., Proc., vol. 23, 1886, pp. 391–410.
HALL, JAMES. Note on some obscure organisms in the roofing slates of Washington County, New York. 29th Rept. State Mus. Nat. Hist. N. Y., 1886, p. 160.
HUNT, T. STERRY. The Taconic question in geology. Mineral physiology and physiography. A second series of Chemical and Geological Essays. 1886, pp. 517–686.
LOW, A. P. Report of the Mistassini expedition, 1884–85. Geol. and Nat. Hist. Surv. Canada, new ser., vol. 1, 1886, pp. 33D.
MATTHEW, G. F. Synopsis of the fauna in division 1 of the St. John group, with preliminary notes on the higher faunas of the same group. New Brunswick Nat. Hist. Soc., Bull. No. 5, 1886, pp. 25–31.
——— The Cambrian faunas of Cape Breton and Newfoundland. (Abstract.) Canadian Record Sci., vol. 2, 1886, pp. 255–258.
——— Illustrations of the fauna of the St. John group continued. No. III. Descriptions of new genera and species (including a description of a new species of Solenopleura by J. F. Whiteaves). Trans. Roy. Soc. Canada, vol. 3, sec. iv, 1886, pp. 29–84. (Proc. for 1885.)
——— Note on the occurrence of Olenellus (?) kjerulfi in America. Am. Jour. Sci., 3d ser., vol. 31, 1886, pp. 472, 473.
SMOCK, JOHN C. A geological reconnoissance in the crystalline rock region, Dutchess, Putnam, and Westchester Counties, New York. 39th Ann. Rep. State Mus. Nat. Hist., 1886, pp. 166–185.
WALCOTT, C. D. Classification of the Cambrian of North America. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 138–157.
——— Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey Bull. No. 30; vol. 4, 1886, pp. 729–1095. (Separate paging, pp. 1–369.)
——— Cambrian age of the roofing slates of Granville, Washington County, New York. Am. Assoc. Proc., vol. 35, 1887, pp. 220, 221. (Separates issued 1886.)
WINCHELL, N. H. New species of fossils. 14th Ann. Rep. Minn. Geol. and Nat. Hist. Surv. 1886, pp. 313–318.
——— Revision of the stratigraphy of the Cambrian in Minnesota. Ibid, pp. 325–337.

1887.

AMI, H., and T. W. E. SOWTER. Report of the geological branch [of Ottawa Field Naturalists' Club.] Ottawa Naturalist, vol. 1, 1887, pp. 93–97.
DANA, JAMES D. On Taconic rocks and stratigraphy, with a geological map of the Taconic regions. Part 2: the Middle and Northern part. Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 270–276, 392–419, pl. 11. (Continued from vol. 29, 1885, p. 443.)
DAWSON, G. M. On certain borings in Manitoba and the Northwest Territory. Royal Soc. Canada, Proc. and Trans., vol. 4, section iv, 1887, pp. 85–99.
[DAWSON, G. M.] [Notes on exploration in the Yukon district.] Science, vol. 10, 1887, pp. 165, 166.
DWIGHT, WILLIAM B. Primordial rocks of the Wappinger Valley limestones and associated strata. Vassar Brothers Inst., Trans., vol. 4, 1887, pp. 206–214. Discovery of additional Potsdam and pre-Potsdam strata of the Olenellus group near Poughkeepsie, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 27–32.
ELLS, R. W. Report on the geology of a portion of the eastern townships of Quebec. Geol. Sur. Canada, 1886, new ser., vol 2, 1887, pp. 1 J–70J.
MCCONNELL, R. G. Report on the geological structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, 1886, new ser., vol. 2, 1887, pp. 1D–41D.
MATTHEW, G. F. Illustrations of the faunas of the St. John group. No. 4. Canadian Rec. Sci., vol. 2, 1887, pp. 357–363, 432. (Abstract.)
——— On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans., vol. 4, section iv, 1887, pp. 147–157.
——— On the kin of the Paradoxides (Olenellus?) kjerulfi. Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 390–392.
ROMINGER, C. Description of Primordial fossils from Mount Stephens, Northwest Territory of Canada. Philadelphia Acad. Sci., Proc. 1887, pp. 12–19.
STEVENSON, JOHN J. A geological reconnoissance of Bland, Giles, Wythe, and portions of Pulaski and Montgomery Counties of Virginia. Am. Philos. Soc. Proc., vol. 24, 1887, pp. 61–108.
WALCOTT, CHARLES D. Fauna of the "Upper Taconic" of Emmons, in Washington County, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 187–199.

1888.

BERGERON, JULES. Note sur la présence de la Faune primordiale (Paradoxidien) dans les environs de Ferrals-des-Montagnes (Hérault). Bull. Soc. géol. France, 3e sér., vol. 16, 1888, pp. 282–285.

CALVIN, S. Notes on the formations passed through in boring the deep well at Washington, Iowa. American Geologist, vol. 1, 1888, pp. 28–31.

CARPENTER, F. R. Notes on the geology of the Black Hills. Preliminary Rep. Dakota School of Mines, on the Black Hills of Dakota, 1888, pp. 11–52.

DAWSON, J. W. On the Eozoic and Paleozoic rocks of the Atlantic coast of Canada in comparison with those of western Europe and the interior of America. Quar. Jour. Geol. Soc. London, vol. 44, 1888, pp. 797–817. Canadian Record of Science, vol. 3, 1888, pp. 182, 183, 230, 231.

HAYDEN, F. V. Report of Montana division of geology. U. S. Geol. Survey, 7th Ann. Rep., for 1885–'86, 1888, pp. 85–87.

HITCHCOCK, C. H. Date of the publication of the report upon the geology of Vermont. Boston Soc. Nat. Hist., Proc., vol. 24, 1888, pp. 33–37.

IRVING, R. D. On the classification of the early Cambrian and pre-Cambrian formations. U. S. Geol. Survey, 7th Ann. Rep. for 1885–'86, 1888, pp. 365–454.

MARCOU, JULES. American Geological Classification and Nomenclature. Cambridge, 1888, pp. 75.

——— The Taconic of Georgia and the report on the geology of Vermont. Memoirs Boston Soc. Nat. Hist., vol. 4, 1888, pp. 105–131.

MATTHEW, G. F. On a basal series of Cambrian rocks in Acadia. Canadian Record Science, vol. 3, 1888, pp. 21–29.

——— On the classification of the Cambrian rocks of Acadia. Canadian Record Science, vol. 3, 1888, pp. 71–81.

——— Illustrations of the fauna of the St. John group, No. IV. Part 1. Description of a new species of Paradoxides (Paradoxides regina). Part 2. The smaller trilobites with eyes (Ptychoparidæ and Ellipsocephalidæ). Royal Soc. Canada, Trans., vol. 5, sec. iv, 1888, pp. 115–166.

SHALER, N. S. On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zoöl. Harvard College, vol. 16, 1888, pp. 13–26, map.

SHALER, N. S., and A. F. FOERSTE. Preliminary descriptions of North Attleborough fossils. Bull. Mus. Comp. Zoöl. Cambridge, vol. 16, 1888, pp. 27–41.

UPHAM, WARREN. The geology of Minnesota. Vol. 2 of final report, 1888, pp. 102–263, 399–425, 612–645.

WALCOTT, C. D. Discovery of fossils in the lower Taconic of Emmons. Am. Assoc. Proc., vol. 36, 1888, pp. 212, 213.

——— The Taconic system of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d ser. vol. 35, 1888, pp. 229–242, 307–327, 394–401.

——— Cambrian Fossils from Mount Stephens, Northwest Territory of Canada. Am. Jour. Sci., 3d ser., vol. 36, 1888, pp. 161–166.

——— The stratigraphical succession of the Cambrian faunas of North America. Nature, vol. 38, 1888, p. 551.

WILLIAMS, H. S. Report of the subcommittee on the Upper Paleozoic (Devonic). International Congress of Geologists, American Committee. Report to the session of the congress held in London, September 17, 1888, pp. 1–31C.

WINCHELL, N. H. The Geology of Minnesota. Vol. 2, of final report, 1888, pp. 1–191, 264–398.

——— A great Primordial quartzite. Am. Geologist, vol. 1, 1888, pp. 173–178.

1889.

BROADHEAD, G. C. The geological history of the Ozark uplift. American Geologist, vol. 3, 1889, pp. 6–13.

CROSBY, W. O. Physical history of the Boston Basin. Lowell Free Lectures, 1889–'90. Boston, 1889, pp. 22.

DWIGHT, W. B. Recent explorations in the Wappinger limestones and other formations of Dutchess County, New York. Am. Jour. Sci., 3d ser., vol. 38, 1889, pp. 139–153.

ELLS, R. W. Second report on the geology of a portion of the Province of Quebec. Geol. Sur. Canada, vol. 3, new ser., 1889, pp. 1K–120K.

FOERSTE, A. F. The paleontological horizon of the limestone at Nahant, Mass., Boston Soc. Nat. Hist., Proc., vol. 24, 1889, pp. 261–263.

KING, WILLIAM. Note on the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt Range. Records of the Geol. Sur. of India, vol. 22, 1889, pp. 153–157.

LANE, ALFRED C. The geology of Nahant. Boston Society Nat. Hist., Proc., vol. 24, 1889, pp. 91–95.

MATTHEW, G. F. How is the Cambrian divided? A plea for the classification of Salter and Hicks. Am. Geologist, vol. 4, 1889, pp. 139–148.

———. On the classification of the Cambrian rocks in Acadia. Supplementary note. Canadian Record Science, vol. 3, 1889, pp. 303–315, 371, 372.

———. On the Cambrian organisms in Acadia. Canadian Rec. Sci., vol. 3, 1889, pp. 383–387.

MCCONNELL, R. G. Notes on the geology of Mount Stephen, British Columbia. American Geologist, vol. 3, 1889, pp. 22–25.

MEADS, A. D. The Stillwater deep well. American Geologist, vol. 3, 1889, pp. 342, 343.

NICHOLSON, H. A., and R. LYDEKKER. A manual of paleontology for the use of students with a general introduction on the principles of paleontology. 3d edition, 2 vols. Edinburgh and London, 1889.

RAND, T. D. A discussion on the rocks of Pennsylvania and New York. New York Acad. Sci. Trans., vol. 8, 1889, pp. 47–51.

SHALER, N. S. The geology of the island of Mount Desert, Maine. 8th Ann. Rep. U. S. Geol. Survey, part 2, 1889, pp. 987–1061.

WALCOTT, C. D. Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, pp. 374–392; vol. 38, 1889, pp. 29–42.

———. Descriptive notes of new genera and species of the Lower Cambrian or Olenellus zone of North America. U. S. National Museum, Proc., vol. 12, 1889, pp. 33–46.

———. Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. National Museum, Proc., vol. 11, 1889, pp. 441–446.

WINCHELL, N. H. The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist. Survey of Minn. 17th Ann. Rep. for 1888, 1889, pp. 5–74.

1890.

COMSTOCK, THEO. B. A preliminary report on the geology of the central mineral region of Texas. 1st Ann. Rep. Geol. Surv. of Texas for 1889, 1890, pp. 239–391.

DANA, J. D. Sedgwick and Murchison; Cambrian and Silurian. Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 167–180.

———. Areas of continental progress in North America and the influence of the conditions of these areas on the work carried forward within them. Geol. Soc. America, Bull., vol. 1, 1890, pp. 36–48.

ETHERIDGE, R., jr. On some Australian species of the family Archæocyathinæ. Trans. Roy. Soc. South Australia, vol. 13, 1890, pp. 10–22.

GILBERT, G. K. Lake Bonneville. Monographs U. S. Geol. Survey, vol. 1, 1890, pp. 438.

HITCHCOCK, C. H. Maine, New Hampshire, Vermont, Rhode Island, and Connecticut. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 2d ed., 1890, p. 86.

MATTHEW, G. F. On Cambrian organisms in Acadia. Roy. Soc. Canada Trans., vol. 7, Proc., sec. iv, 1890, pp. 135–162.

MCGEE, W J. The southern extension of the Appomattox formation. Am. Jour. Sci., 3d ser., vol. 40, 1890, pp. 15–41.

PEALE, A. C. Report of Dr. A. C. Peale (on the Montana division of geology). U. S. Geol. Surv., 10th Ann. Rep., 1890, pp. 130–132.

SEARS, JOHN H. The stratified rocks of Essex County (Massachusetts). Essex Institute, Bull., vol. 22, 1890, pp. 31–47 (separate, pp. 17).

WALCOTT, C. D. A review of Dr. R. W. Ells's second report on the geology of a portion of the province of Quebec; with additional notes on the "Quebec group." Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 101–115.

——— Description of new forms of Upper Cambrian fossils. U. S. National Museum, Proc., vol. 13, 1890, pp. 267–279.

——— The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rept. U. S. Geological Survey, Part I, 1890, pp. 509–763, pls. 49–98.

WINCHELL, N. H., and H. V. WINCHELL. The Taconic iron ores of Minnesota and of western New England. Am. Geologist, vol. 6, 1890, pp. 263–274.

1891.

GEIGER, H. R., and ARTHUR KEITH. The structure of the Blue Ridge near Harper's Ferry. Bull. Geol. Soc. America, vol. 2, 1891, pp. 155–164.

HAYES, C. WILLARD. The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, Vol. 2, February, 1891, pp. 141–154.

MATTHEW, G. F. Illustrations of the fauna of the St. John group No. 5. Roy. Soc. of Canada Trans., vol. 8, sec. iv, 1891, pp. 123–166.

NASON, FRANK L. The Post-Archean age of the white limestones of Sussex County, New Jersey. Am. Geologist, vol. 7, 1891, pp. 241–252.

SHALER, N. S., and H. S. WILLIAMS. On the geology of Little Falls, New York. Bull. Geol. Soc. America, vol. 2, 1891, pp.

SMITH, EUGENE A. Geological structure and description of the valley regions adjacent to the Cahaba Coal Fields. Geol. Survey of Alabama. Report on the Cahaba Coal Fields, by Joseph Squire. Pt. II, 1890 (issued March, 1891), pp. 133–180.

WOLFF, J. E. On the Lower Cambrian age of the Stockbridge limestone at Rutland, Vermont. Bull. Geol. Soc. America, vol. 2, 1891, pp. 331–337.

CHAPTER II.

HISTORICAL REVIEW OF THE GEOLOGIC AND PALEONTOLOGIC WORK.

The scope of this review is limited, with a few exceptions, to the notice of papers and memoirs that have added something original to the preexistent knowledge of the rocks and faunas now referred to the Cambrian group.

Several methods of presenting the historical data have suggested themselves.

(1) Chronologic; (2) Geographic and chronologic; (3) Chronologic, geographic, and stratigraphic.

(1) *Chronologic.*—This method necessitates reference to papers in the order of their publication, whether they treat of Cambrian rocks in Newfoundland, New York, Alabama, or Nevada. All is subservient to the chronologic record.

(2) *Geographic and chronologic.*—This method permits of the chronologic grouping of the papers referring to the rocks under consideration in geographic areas.

(3) *Chronologic, geographic, and stratigraphic.*—This third and more comprehensive method arranges the review in the form of a statement of the historical data as in the second method, with the addition of treating of such primary divisions separately as may be thought worthy of such consideration. To this there may also be added, in exceptional instances, the chronologic arrangement of the discoveries and opinions of some of the more prominent investigators and authors.

The second method is adopted in this review in connection with the third, where the latter is necessary in order to present more clearly the evolution of the present knowledge of the rocks and fauna of the Cambrian group.

The Cambrian group can usually be divided into three primary divisions. *First*, the Lower Cambrian; *second*, Middle Cambrian; *third*, Upper Cambrian. This nomenclature will be used throughout the review, when it is necessary to refer to a standard generally known.

Rocks of Cambrian age occur on the North American continent in four principal geographic areas or geologic provinces. In reviewing the literature it is possible, owing to the investigators in each province having limited their work to their respective provinces, to present the history of discovery and publication in each by itself, as follows:

I. *The Atlantic Coast or Eastern Border Province.*

II. *The Appalachain Chain.*

III. *The Rocky Mountain or Western Border Province.*

IV. *The Interior Continental or Central Province.*

The record of paleontologic investigation in each province will follow the geologic review.

ATLANTIC COAST PROVINCE.

The Atlantic coast province includes the deposits on the island of Newfoundland, the provinces of Nova Scotia and New Brunswick and Cape Breton, and the States of Maine, New Hampshire, and eastern Massachusetts.

NEWFOUNDLAND.

Systematic geologic investigation in Newfoundland began with Prof. J. Beete Jukes, who in 1843[1] published a report of his studies in field and office. He describes the relation of the strata at the base of the Paleozoic section (now referred to the Olenellus zone), to the unconformably subjacent crystalline rocks about Conception Bay, and mentions the red shales in which the Olenellus fauna is now known to occur, as well as the green and dark shales of the Paradoxides zone, as subsequently known. A description is given of the upper slate formation as shown on the islands in the bay, under the name of Bell Island shale and grits; and of the lower slate under the name of St. John's slate, 2,000 to 3,000 feet thick, as seen near the town of St. John's; also the superjacent Signal Hill sandstone, about 800 feet thick.[2] In the absence of fossils no attempt was made to correlate the formations with those of England. On the map accompanying the report the geographic distribution is given of the lower slate (St. John's) and of the upper slate (Bell Island) formations about Conception Bay and Smith Sound.

Two years later Capt. H. W. Bayfield[3] described a sandstone with subjacent red and white limestone on the Straits of Belle Isle, which he stated contained a species of Cyathophyllum. This is the first notice of the Lower Cambrian rocks containing Archaeocyathus, and it is the second recorded discovery of fossils now referred to the Olenellus zone.

At a meeting of the Boston Society of Natural History, April 20, 1859, Dr. C. T. Jackson exhibited a trilobite from the calcareous slate of St. Mary's Bay, Newfoundland, which he thought identical with *Paradoxides harlani* from Braintree, Massachusetts. He said that this formation could be followed, though in an interrupted line, from Braintree to Newfoundland.[4]

In 1859 Mr. J. W. Salter[5] received a specimen of the genus Paradox-

[1] General report of the geological survey of Newfoundland in 1839 and 1840, pp. 160, 2 pls., London, 1843.

[2] Op. cit. pp. 55–66.

[3] On the junction of the transition and primary rocks of Canada and Labrador. Quart. Jour. Geol. Soc., London, vol. 1, 1845, pp. 450–459.

[4] On a trilobite from Braintree. Boston Soc. Nat. Hist., Proc., vol. 7, 1859, p. 54.

[5] On the fossils of the Lingula-flags or "Zone Primordiale." Quart. Jour. Geol. Soc., London, vol. 15, 1859, pp. 551–555.

ides, collected from the upper slate of St. Mary's Bay, Newfoundland, which he described under the name of *Paradoxides bennetti*, calling attention to its relation to *Paradoxides spinosus* and *P. bohemicus*, of Bohemia.

In 1862, Prof. Jukes, referring to his work in Newfoundland, stated that he included under the upper slate formation the Bell Isle shale and gritstone and variegated slate; and in the lower slate formation the Signal Hill sandstones and St. John's slate. He says he did not find any fossils in them, but that Mr. C. Bennett subsequently found trilobites of the genus Paradoxides (named *P. bennetti* by Mr. J. W. Salter) in the slates on the west side of St. Mary's Bay. "These slates belong to the group I called the St. John's slate, which is covered conformably by the Signal Hill sandstone. The Variegated slate group, on the other hand, passes up into the Bell Isle shale and gritstone, and near Brigus Harbor, in Conception Bay, may be seen to rest unconformably on the St. John's slate" (as described in 1843).[1] This is the unconformity now recognized between the Cambrian and Algonkian rocks.

Eighteen years after Captain Bayfield had reported on the strata of the north side of the straits of Belle Isle, Sir William E. Logan[2] described the strata resting on the gneiss as red and green sandstones, 231 feet thick, overlain by gray, reddish, and greenish limestone. In the limestone a number of fossils were found which Mr. Billings identified with those found in the "Red Sandrock" of Vermont. The formation was referred to the Lower Potsdam by Logan. Fifteen miles across the straits, on the Newfoundland coast, the rocks are apparently of Calciferous age; and he concluded that the Potsdam sandstone zone was buried beneath the waters of the Straits.[3] In the description of the section at Bonne Bay, on the west coast of Newfoundland,[4] it is compared with that at the Straits of Belle Isle; and on pages 865–867, the section at Bonne Bay is given in detail. Of this 1,711 feet are, by the contained fossils, referred to the Potsdam group.

In the report of the Geological Survey of Newfoundland for 1864[5] a summary is given of the then existing view of the succession of the Lower Paleozoic rocks in North America. For Newfoundland the succession of the rocks now referred to the Cambrian is Upper Potsdam, Lower Potsdam, and St. John's group, and Newfoundland is cited as the locality where the lower portion of the series is complete. The lowest, or St. John's group, is correlated with that of St. John, New Brunswick, and the Paradoxides beds of Braintree, Massachusetts. The lower Potsdam is represented by several hundred feet of limestones and

[1] The student's manual of geology. Second edition. Edinburgh, 1862, p. 457.

[2] Geological survey of Canada. Report of progress from its commencement to 1863. Montreal, 1863, pp. 983, 11 plates. Atlas of maps and sections, with an introduction and appendix. Montreal, 1865. 9 maps and sections.

[3] Op. cit., p. 288.

[4] Op. cit., p. 293.

[5] Logan, W. E., Lower Silurian Rocks of North America. Geol. Surv. Newfoundland, Rep. Prog. for 1864, Montreal, 1866, pp. 45, 46. Revised edition, 1881, p. 49.

sandstones on the Straits of Belle Isle, and on White Bay, Newfoundland, and by the slates of St. Albans and Georgia, Vermont. The Upper Potsdam is that of Wisconsin and Minnesota, represented in the typical Potsdam of New York. This horizon is not recognized in the northern part of Newfoundland, but occurs on Conception Bay, in the southeastern part. The tabulation made by Logan has been followed very largely by all writers upon American geology, and the succession was not changed until 1888, when it was discovered that the St. John group of Mr. G. F. Matthew was above the Lower Potsdam of Billings and Logan.

The Geological Survey of Newfoundland, under the direction of Dr. Alexander Murray, added materially to our knowledge of the Lower Paleozoic rocks. All the strata beneath the Calciferous or Quebec group were referred to the Potsdam group.[1] In the neighborhood of Canada Bay, on the east coast, the entire series referred to the Potsdam has a thickness of 1,153 feet, of which the lower 700 feet belong to the Lower Cambrian zone, as shown by *Olenellus vermontana* occurring in the upper portion.[2] In the report of field work for 1868, Dr. Murray[3] describes the rocks about Conception Bay, in the southeastern portion of the island. Of the lowest bed exposed on Manuel's Brook, a small stream that flows into Conception Bay, he says: "On Manuel's Brook a very coarse conglomerate may be seen, in strong and moderately regular beds, resting directly upon the syenitic gneiss of the valley above. * * * About 400 yards below the bridge the conglomerate is overlaid conformably by a set of dark brown or blackish shales, * * * with some hard calcareous beds interstratified," and this series extends down the stream nearly to the bay.[4] Dr. Murray also describes, in a section at Topsail Head, a gray compact limestone in strong solid beds, 1 to 2 feet thick, showing a vertical thickness of about 100 feet, together with some interstratified shale. The limestone is subjacent to a dark brown, finely laminated shale. Detailed sections are given of the shales and sandstones exposed on Kelly's and Great Bell Islands, Conception Bay; the former has a thickness of 712 feet and the latter of 476 feet. A summary of the rocks referred to the Lower Silurian gives an entire thickness of 3,880 feet.[5] Figures of five sections accompany the text, in which the unconformity between the Lower Silurian rocks and the subjacent intermediate system or Huronian and the Archean is well shown. The subjacent slates and Signal Hill sandstones of Jukes are referred by Dr. Murray to the Cambrian group on account of fossils having been found there, which Mr. Billings described as *Aspidella terra norica* and Arenicolites.[6]

[1] Sequence and distribution of the rocks of the great Northern Peninsula. Geol. Surv. Newfoundland, Rep. Prog. for 1864, Montreal, 1866, pp. 10, 44. Revised edition, 1881, pp. 5-47.

[2] Op. cit., p. 10.

[3] Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868, St. John's, 1868, p. 68. Revised edition, 1881, pp. 154-167.

[4] *Op. cit.*, p. 154.

[5] *Op. cit.*, pp. 157–160.

[6] *Op. cit.*, p. 144.

In the report for 1869 a description is given of the Lower Paleozoic rocks studied by Mr. Howley as they occur on Trinity Bay and St. Mary's Bay.[1] The variegated slates of Jukes are described as containing Paradoxides and the superjacent argillaceous shales and sandstones carry Cruziana and other fossils. These last represent the rocks of the Bell Islands in Conception Bay. In the report for 1870[2] a summary is given of the then existing knowledge of the Primordial formations in southeast Newfoundland. In descending order the upper formation is a brown and black micaceous shale with the gray micaceous sandstones of Great Bell Isle, Conception Bay. The organic contents are: Two species of Lingula, four species of Palæophycus, *Eophyton linnæanum* of Torrell, another Eophyton and *Cruziana semiplicata* Salter. Thickness, 476 feet. He says that the slates of Little Bell Isle and the beds of shale beneath the water are considered to have a thickness of 1,426 feet, to which the Kelly's Island sandstone and shale are to be added, with a thickness of 720 feet. [As now known this forms the upper division of the Cambrian.] Beneath this he describes the black slates, with *Paradoxides bennetti*, having a thickness of 150 feet. On St. Mary's Bay this division, united with the red, green, and black shales or slates, in which *Paradoxides bennetti*, *Conocephalites gregarius* and other fossils were recognized, has a thickness of 1,045 feet. [This forms the middle division of the Cambrian as now known.] Below this the hard thick beds of gray and reddish limestone of Topsail Head, Brigus South Head, Conception Bay, and the Little Salmonier River of St. Mary's Bay are united with various outcrops of red, green, and blackish argillaceous slates and a series of sandstones below. [These form the lower division of the Cambrian as now known.] The total thickness of the section described is 5,972 feet.[3] Several sections are illustrated to show the relation of the Primordial-Silurian to the subjacent rocks.

In the report for 1872 the Primordial-Silurian rocks are described as they are exposed on Trinity Bay, etc., by Dr. Murray.[4] He states that on paleontological grounds Mr. Billings is disposed to draw a marked distinction between the upper strata of the section of 1870 and the lower members of that section, in consequence of an apparent hiatus or break in organic development between the Paradoxides beds and the fossiliferous strata of Great Bell Island in the Conception Bay section. The lower measures he [Billings] appears to regard as the equivalent of the lower Lingula flags of Great Britain, or the Menevian group of Salter and Hicks; while the upper parts contain forms in some degree typical of the horizon of the Upper Potsdam.[5] This is followed by a

[1] Murray, Alexander. Of the rocks and associated minerals [of Bonavista Bay, etc.]. Report upon the geological survey of Newfoundland for 1869. Revised edition. 1881, pp. 200-203.

[2] Murray, Alexander. Of Primordial, Silurian, and related formations. Geol. Surv. Newfoundland for 1870, St. John's, 1870, pp. 30-43. Revised edition, 1881, pp. 232-241.

[3] Op. cit., pp. 237-239.

[4] Distribution of the formations [of Avalon]. Report upon Geol. Surv. of Newfoundland for 1872. St. John's, 1873. pp. 14-34. Revised edition. London, 1881, pp. 285-297.

[5] Op. cit., p. 291.

list of the species described by Mr. Billings from the Paradoxides zone and the strata of Great Bell Island.

Prof. John Milne traveled extensively along the coast of Newfoundland, and published the results of his geologic studies in association with the "Notes on Geology" by Alexander Murray.[1] The Primordial-Silurian is spoken of as a separate division; then, superjacent to the rocks of this formation, come the Potsdam and Calciferous. There does not appear to be any additional data to that already given in the report on the geology of Newfoundland by Dr. Murray.

When describing some fossils collected by Mr. T. C. Weston, of the Canadian Geological Survey, in 1874, from St. Mary's, Trinity, and Conception Bays, Newfoundland, Prof. J. F. Whiteaves states that the paleontological evidence sustains the view of Sir W. E. Logan that the slates of St. John's, Newfoundland, probably belong to the same horizon as the Acadian or St. John group of St. John, New Brunswick.[2] Of the deposits on the islands of Conception Bay he says: "From Mr. Murray's report already quoted it would appear that the shales of Kelly's Island are not quite so old as those of Manuel's Brook, but that they are older than the Menevian sandstones of Great Bell Island."[3]

Dr. Murray appears to have considered the Potsdam zone as above the Primordial beds of Newfoundland. This is shown in the chapter on the "Geology of Newfoundland," where a summary of the geology is presented as taken from Dr. Murray's work.[4]

Prof. Alpheus Hyatt, in his expedition to Newfoundland, visited the north coast of the Straits of Belle Isle, and collections were made at Anse au Loup and Amour Cove from the "so-called Potsdam sandstones and limestones of the Canadian survey. The observations made at these points indicate a fauna quite distinct from those of any of the limestones or slates of the west coast of Newfoundland. The absence of Cephalopoda and the prevalence of primitive forms of Archæocyathus show the rocks to be probably older than those of the Quebec group at Port au Choix and other localities. The primitive sponges, or Archæocyathi, have here replaced corals completely, and may be described as reef-builders, since numerous hummocks and masses and parts of the strata are formed entirely of their remains. Immediately below these limestones, and conformable with them, lie the red sandstones, several layers of which are perforated with Scolithus burrows."[5]

A brief summary of the Lower Cambrian rocks of Newfoundland, was given by Mr. C. D. Walcott, in a study of the Cambrian faunas of

[1] On the rocks of Newfoundland. Geol. Mag., new ser., decade II, vol. 4, 1877, pp. 251–262.

[2] On some Primordial fossils from southeastern Newfoundland. Am. Jour. Sci., 3d ser., vol. 16, 1878, p. 225.

[3] Op. cit., p. 226.

[4] Hatton, Joseph, and M. Harvey. Geology of Newfoundland. Newfoundland, the oldest British colony, its history, its present condition, and its prospects in the future. London, 1883, pp. 178–187. American edition. Boston. 1883, pp. 150–157.

[5] Expedition to Newfoundland. Boston Soc. Nat. Hist. Proc., vol. 23. 1886, p. 319. Cruise of the *Arethusa*. Science, vol. 6, 1885, p. 386.

North America[1] when discussing the stratigraphic position of the Olenellus fauna. In it he says[2] that the only locality known where the two faunas occur in the same geographic area is on Conception Bay, Newfoundland; and special stress is placed on the occurrence at Topsail Head of several species of fossils typical of the Olenellus zone at the Straits of Belle Isle. This fauna was referred to the Middle Cambrian,[3] although Dr. Murray states in his section of 1868 that Mr. Billings referred the species to the Potsdam.[4] By this Mr. Billings probably meant his lower Potsdam, which is now (1890) included in the Lower Cambrian.

In an abstract of a paper on the Cambrian faunas of Cape Breton and Newfoundland, published in advance of the paper read before the Royal Society of Canada, Mr. G. F. Matthew[5] classifies the horizons of the Cambrian as follows:

(1) The horizon of *Paradoxides kjerulfi*.
(2) The horizon of the Conocoryphees.
(3) The horizon of *Paradoxides tessini*.
(4) The horizon of *Paradoxides spinosus*.
(5) The horizon of *Paradoxides davidis*.

It is stated[6] that "in this classification of the various Newfoundland horizons in the Paradoxides zone Mr. Matthew has placed that of *Paradoxides kjerulfi* first or oldest, because that is its position in Scandinavia." In the final paper[7] he speaks of the fossils found at Topsail Head, and Brigus on Conception Bay, mentioning *Agraulos strenuus*, Iphidea (allied to *Iphidea bella* Billings), and *Stenotheca paupera* Billings. He says these fossils do not give sufficiently firm indications to make it clear that they are older than some other horizons mentioned hereafter. He then describes the fossils of the Paradoxides zone. A new species, *Solenopleura bombifrons*, is described from the limestone of Topsail Head.[8]

In the summer of 1888 Mr. C. D. Walcott made a careful study of the Cambrian section in Newfoundland, and determined the Olenellus zone to be beneath the Paradoxides zone, and not above it, as arranged by Logan in his scheme of 1864. A detailed section of the Cambrian strata on Conception Bay was published, with lists of the fossils occurring at the different horizons in it.[9]

---

[1] Second contribution to the studies on the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, vol. 4, 1886.

[2] Op. cit., p. 49.

[3] Op. cit., p. 29.

[4] Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868. Revised edition, 1881, "P. 1" of section, p. 157.

[5] The Cambrian faunas of Cape Breton and Newfoundland (abstract). Can. Record Sci., vol. 2, 1886, pp. 255–258.

[6] Op. cit., p. 258.

[7] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans., vol. 4, section iv, 1887, pp. 147–157.

[8] Op. cit., p. 156.

[9] The stratigraphical succession of the Cambrian faunas of North America. Nature, vol. 38, 1888, p. 551. Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 374–392; vol. 38, 1889, pp. 29–42.

NOVA SCOTIA.

The altered or metamorphic slate belt of the Atlantic coast of Nova Scotia is represented on an early geological map by Dr. Abraham Gesner[1] as extending from Cape Canso to Cape Sable. He states that the area is within the primary district and composed principally of granite, gneiss, and mica slate. A general description of the rocks is given in the account of the local geology of the townships in which they occur.

At a meeting of the Geological Society of London on May 10, 1843, Dr. Gesner[2] presented to the society a geological map of Nova Scotia, accompanied by a memoir on the geology. In the text[3] the lowermost of the Silurian rocks devoid of animal remains is referred to the Cambrian. The map was not published with his paper. It appeared in 1845[4] in connection with papers by Mr. Richard Brown, on the geology of Cape Breton, and Mr. J. W. Dawson, on the Lower Carboniferous rocks or gypsiferous formation of Nova Scotia. The strata now provisionally included in the Cambrian group are indicated on the map as micaceous and chloritic slates, clay slate, quartz rock, and graywacke slate. They extend entirely around the central area of granite and syenite, and are separated from the Atlantic coast by a broad belt of color designated as granite. At a later date Gesner described the stratified non-fossiliferous rocks or Cambrian group of Nova Scotia[5] as an extended belt of hornblende slate, chlorite slate, clay slate, graywacke slate, and quartzite, succeeding the granite and its associates, and with them occupying almost the whole of the Atlantic side of the province. No fossil remains have been found in any of these metamorphic masses.

In 1850 Dr. J. W. Dawson described the Atlantic coast series as follows:

> The prevailing stratified rocks in this group are compact and flaggy gray quartzite (often weathering white), mica slate, and clay slate, the latter usually of dark colors, and occasionally passing into flinty slate and quartzite. * * *
>
> The hypogene rocks associated with them are white and flesh-colored granite, which has penetrated the metamorphic rocks in large irregular bands and masses.[6]

As a result of his study of this group of rocks Dr. Dawson concluded that they belonged either to some of the older members of the Silurian system or to a still earlier period. In the first edition of the Acadian Geology Dr. Dawson stated that the rocks are certainly older than the Devonian; and he was inclined to believe that they represented the Potsdam sandstone and Utica and Hudson River shales, in an altered condition.[7] On the accompanying map their geographic distribution

[1] Remarks on the geology and mineralogy of Nova Scotia. Halifax, N. S., 1836, pp. 272.

[2] A geological map of Nova Scotia, with an accompanying memoir. Geol. Soc. London, Proc., vol. 4, 1843, pp. 186–190.

[3] Op. cit., p. 187.

[4] Geological Map of Nova Scotia. (Accompanying papers by J. W. Dawson and Richard Brown.) Quart. Jour. Geol. Soc., London, vol. 1, 1845, oppo., p. 23.

[5] The industrial resources of Nova Scotia. Halifax, N. S., 1849, pp. 233, 234.

[6] *On the* metamorphic and metalliferous rocks of eastern Nova Scotia. Quart. Jour. Geol. Soc., London, *vol. 6*, 1850, p. 348.

[7] *Acadian Geology*, 1st Edition, Edinburgh, 1855, p. 357.

is shown and in the legend they are noted as "perhaps altered Lower Silurian" strata.

In a supplementary chapter to the first edition the slates and quartzites of the Atlantic coast belt are spoken of, and it is suggested that they may be a continuation of the Primordial zone of Newfoundland, in which Paradoxides have been found.[1] Mr. E. Billings reviews this supplementary chapter and says:[2] "We are strongly inclined to the belief that this supposition will yet turn out to be well founded."

In 1862 the slates of the Nova Scotia metamorphic slate belt were referred to the Taconic System.[3] A more detailed description of the rocks was published by Dr. J. W. Dawson, in 1868, in which they are stated to be formed of granite, gneiss, mica slate, quartz rock or quartzite, and clay slate. The granite appears to be intrusive, and the gneiss is considered a product of a metamorphism or baking of sedimentary rocks. The clay slate or argillaceous slate abounds, and is usually, along the Atlantic coast, of a gray and black color, varying very much in texture and hardness.[4] He states that the series has not afforded fossils, but it appears to be a continuation of the older slate series of Mr. J. B. Jukes in Newfoundland, which has afforded trilobites of the genus Paradoxides. On the map accompanying the volume the geographic distribution of the series is clearly exhibited.

In a general description of the Nova Scotia gold field Mr. J. Campbell[5] publishes a section across the gold-bearing rocks of the Atlantic coast, in which the arrangement and relative position of the different groups of strata are well shown. There is a great thickness of quartzite subjacent to blue and gray slates divided midway by the "black rock." Very few details are given of the section, as the report is mainly devoted to a description of mining and the mode of occurrence of gold.

When reporting upon the Waverly gold district Prof. H. Y. Hind stated that he had found *Palæotrochus minor* and *Palæotrochus major* of Emmons, besides numerous concretionary forms, in the Waverly beds. He considers (*a*) that these fossils, if identical with those from North Carolina, probably establish the age of the gold-bearing rocks of Nova Scotia; (*b*) that they occur near the base of the Lower Silurian System; (*c*) that they belong to the upper part of the Potsdam formation and the lower part of the Calciferous formation, and (*d*) that they are subjacent to the great mass of serpentine and red slates, discovered by Dr. Honeyman in Antigonish, which belong to the Quebec group. The gold series is correlated with that described by Dr. Emmons in North

[1] Supplementary chapter to the Acadian Geology, Edinburgh, 1860, p. 53.

[2] [Review of] Acadian Geology and a Supplementary Chapter thereto. Canadian Nat., vol. 5, 1860, pp. 450–455.

[3] Marcou, Jules. [The slate of Nova Scotia, metamorphic Taconic rock.] Boston Soc. Nat. Hist., Proc., vol. 9, 1862, p. 47.

[4] Acadian Geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, 2d. ed. London, 1868, pp. 613–615.

[5] Report on the Gold Fields of Nova Scotia. Halifax, 1863, pp. 12.

Carolina.[1] In a paper presented to the Geological Society of London,[2] and subsequently published in the report on the Sherbrooke gold district of Nova Scotia, Prof. Hind describes the gold-bearing rocks of Nova Scotia as follows:

> The gold-bearing rocks of Nova Scotia are of Lower Silurian age, and rest either on Huronian strata or, where these have been removed by denudation, on the old Laurentian gneiss. The gold is found chiefly in beds of auriferous quartz of contemporaneous age with the slates and quartzites composing the mass of the series, which in Nova Scotia is 12,000 feet thick, and the auriferous beds are worked, in one district or another, through a vertical space of 6,000 feet.[3]

In a report on the gneissoid series underlying the gold-bearing rocks of Nova Scotia the same writer[4] states that he has provisionally referred the gold-bearing series to the Lower Silurian, but that conclusive evidence derived from fossils has not been obtained from the gold-bearing slates and quartzites. Since the discovery of the forms resembling the Palæotrochus of Emmons, noticed in his report on the Waverly district, he has sent to Mr. Billings slabs containing supposed fossils from the Sherbrooke rocks. Mr. Billings thought that a species of Orthis and an Eospongia were indicated. In describing the gold-bearing rocks under the head of "Lower Silurian" Prof. Hind[5] says:

> The known gold-bearing rocks of Nova Scotia consist of quartzites, sandstones, and grits, interstratified with argillaceous slates and thin conformable beds of auriferous quartz. This portion has an ascertained thickness exceeding 9,000 feet. * * * The thickness of the black slates in Nova Scotia exceeds 3,000 feet, so that the gold-bearing rocks of the province have a known thickness of 12,000 feet.

The essential parts of the description in the last paper are also printed in the American Journal of Science.[6]

In his report on the gold fields of Quebec and Nova Scotia, Dr. A. R. C. Selwyn[7] speaks of the geological position of the Atlantic coast series of stratified gold-bearing slate and quartzite, stating that all former observers are agreed that they probably belong to the Lower Silurian series. His first impression of them was that they represented the groups known in Britain as the Harlech grit or quartzite, and the Lingula-flag series. He discovered in the gray sandy and flaggy pyritous slates at the Oven's Bluffs numerous specimens of the genus Eophyton, and states that Mr. Billings regarded this genus as characteristic of the Primodial Silurian epoch. He then gives an account of the distribution of the genus Eophyton, and in conclusion says: "In

---

[1] Report on the Waverly Gold District, with geological maps and sections. Halifax, 1869, p. 61.

[2] On two gneissoid series in Nova Scotia and New Brunswick, supposed to be the equivalents of the Huronian (Cambrian) and Laurentian. Quart. Jour. Geol. Soc., London, vol. 26, 1870, pp. 468–470.

[3] Report on the Sherbrooke gold district, together with a paper on the gneisses of Nova Scotia and an abstract of a paper on gold mining in Nova Scotia. Halifax, N. S., 1870, p. 3.

[4] Preliminary report on a gneissoid series underlying the gold bearing rocks of Nova Scotia, and supposed to be the equivalent of the Laurentian system. Halifax, N. S., 1870, pp. 14.

[5] Op. cit., p. 8.

[6] On the Laurentian and Huronian series in Nova Scotia and New Brunswick. Am. Jour. Sci., 2d ser., vol. 49, 1870, pp. 351–353.

[7] Notes and observations on the gold fields of Quebec and Nova Scotia. Geol. Surv. Canada. Report Prog. for 1870–'71, 1872, pp. 268–270.

general aspect, and in the succession of the beds the whole series in Nova Scotia closely resembles the Cambrian and Lingula-flag series of North Wales."[1]

Dr. J. W. Dawson reviews his studies of the Atlantic coast belt of Nova Scotia in the supplement to the second edition of the Acadian Geology,[2] and places the slates and quartzite in the Cambrian. He states that the evidence of fossils in determining the precise age of these rocks is unfortunately as yet somewhat imperfect, and quotes Prof. Hind as saying that the entire thickness of the series is 12,000 feet; of this the lower or quartzite and slate division comprises about 9,000 feet, and the upper or ferruginous slate division about 3,000 feet.

On the colored geological map of the Dominion of Canada, published in 1882, the Cambrian rocks of Nova Scotia are made to extend from near the northeastern point of the peninsula south to Sable River, where they are interrupted by a mass of granite that extends to Harrington Harbor. From this point around the western slope to Annapolis Basin they occupy a wide strip along the shore. As represented on the map they occupy nearly one-half of the area of Nova Scotia.

In 1888 Sir William Dawson reviewed the rocks referred to the Cambrian group on the Atlantic coast of Canada,[3] stating that the Atlantic coast or gold series of Nova Scotia in their western extension appeared to rest on rocks of Huronian aspect. He also says:

> It has unfortunately afforded no well-characterized fossils. The markings called Eophyton and certain radiating bodies (Astropolithon) found in it are, however, similar to those occurring elsewhere in Lower Cambrian rocks. Murray was disposed to regard this formation as corresponding to his Huronian in Newfoundland; but it does not agree with this either in mineral character or in fossils, and is perhaps rather to be regarded as a great development of the lowest member of the Cambrian, an exaggerated equivalent of the Harlech grits and Llanberris slates. In this case, however, it may be expected that it will yet afford true Cambrian fossils.[4]

NEW BRUNSWICK AND CAPE BRETON.

In the report for 1842 on the geology of New Brunswick Dr. Abraham Gesner[5] uses the term "Cambrian system." He says:

> This name has been applied to a group of rocks situated beneath the "Silurian" strata, from which it is not always separated by any very distinct line of demarcation, so far as its lithological character is concerned. The few organic remains, however, found in this group are sufficiently characteristic to make it appear that the forms of animal life during the period of the accumulation of its strata were different from those found in the upper Silurian rocks.

---

[1] Op. cit., p. 271.

[2] Supplement to the second edition of Acadian Geology, containing additional facts as to the geological structure, fossil remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, London, 1878, pp. 81–83.

[3] On the Eozoic and Paleozoic rocks of the Atlantic coast of Canada, in comparison with those of western Europe and of the interior of America. Quart. Jour. Geol. Soc. London, 1888, vol. 44, pp. 804–807. Canadian Record of Science, vol. 3, 1888, pp. 182, 183, 230, 231.

[4] Op. cit., p. 805.

[5] Report on the geological survey of the Province of New Brunswick, with a topographical account of the public lands and districts explored in 1842. St. John, 1843, p. 72.

The rocks of this group extend from the American boundary line and cross the St. John a little above the Meductic, and proceed in a northeast direction toward Bathurst. * * *

The strata consist chiefly of grauwacke, grauwacke slate, and clay slate. The grauwacke may be compared to a very compact sandstone. There are also beds of conglomerate, containing bowlders and pebbles of almost every variety of rock. The cementing matter is generally calcareous or argillaceous; but it is sometimes silicious, and the beds change imperceptibly into quartz rock. The slates are of different colors; red, blue, and green are often seen. Many of them contain lime, and others will supply roofing slate.

The local details of the distribution of this series are not given, nor is the locality of the city of St. John mentioned. Portions of the rocks mentioned by Dr. Gesner are, however, now included in the Cambrian group.

In his third report Dr. Gesner[1] recognizes two series of rocks, both of which are referred to the Silurian age. The upper group consists of limestones, slates, and sandstones, containing the remains of plants, mollusks, etc. The older group is formed of conglomerates, gray slates, sandstones, talcose slates, and the trap beds of Mispeck and Black Rivers.

On a map prepared by Dr. James Robb,[2] the geographic distribution of the formations described by Dr. Gesner is outlined, and under the "Cambrian system" we find the indicated distribution of the Cambrian rocks to include Carboniferous, Devonian, Lower Silurian, and Cambrian as now known. In the text of the volume accompanying the map Mr. J. F. W. Johnston[3] describes the geographic distribution of the rocks and also their general character. He states that the rocks of the Cambrian are distinguished from those of the Silurian by their greater hardness and by their containing less lime.

In speaking of the rocks referred to the Lower Silurian and Cambrian, by Gesner and Robb, Mr. J. W. Dawson[4] states that for the distribution of these rocks, as indicated on the map, he was indebted principally to the map prepared by Dr. Robb. Of the rocks he says:

I do not think that at present there is any good ground for separating the so-called Cambrian rocks from those last mentioned [Silurian], though it is quite probable that they may belong to an older formation, or that they may be older members of the same formation.

When relating the results of a visit to New Brunswick Prof. W. B. Rogers[5] described, by the aid of a section, the stratigraphic features exhibited at the junction of the older and less ancient groups of strata on the St. John's and Kennebecasis Rivers, a few miles above the city

[1] Third report on the geological survey of the province of New Brunswick. St. John, 1841, pp. 5-11.

[2] [Letter on the geological structure of New Brunswick.] Report on the agricultural capabilities of the province of New Brunswick, by J. F. W. Johnston. Fredericton, 1850. pp. 12, 13.

[3] Report on the agricultural capabilities of the province of New Brunswick. Fredericton, 1850. pp. 17, 18.

[4] Acadian Geology, first edition, 1855, pp. 324, 325.

[5] Remarks on the geology of the neighborhood of St. John New Brunswick. Boston Soc. Nat. Hist., Proc., vol. 7, 1861, p. 176.

of St. John, as observed by Dr. Robb and himself. Referring to the probable ages of the two groups he states that the only fossils discovered consist of vegetable impressions found by Dr. Robb at several localities, and some black scale-like fragments of shells that he found about the city of St. John in loose pieces of siliceous slate. At several points the layers of rock in place are crowded with these remains, the more entire of which presented the form and markings of a Lingula.

Dr. J. W. Dawson described in 1862 the strata about St. John, and published a section[1] that includes the shales and slates of the vicinity of the city; and, in the same section, a series of beds which have since proved to be of Devonian age. He states that the age of the lower members was less certain. They may represent either the Middle and Lower Devonian, or may be in part of Silurian age. "The only determinable fossil, the Lingula of the St. John shales, affords no decisive solution of this question."

In proposing a classification for the pre-Devonian rocks of New Brunswick, Mr. G. F. Matthew[2] states that Gesner's older group is to a great extent younger than his upper series. He reviews the classification of Dr. Dawson[3] dividing the formations into several groups, proposing the name St. John group for Nos. 5 and 6 (in part) of Dawson's section of 1862. He says that the St. John group is formed of several zones of soft, black, dark gray, finely laminated shales, alternating with zones of coarser gray slates, containing numerous thin beds of fine-grained sandstone, the whole having a thickness of about 3,000 feet. The fossils noticed were a Lingula, a Conchifer, Annelids and Coprolites.[4] The Coldbrook group, No. 6 of Dawson, in part, is given a thickness of 3,000 feet or more composed of greenish gray slate, bright red slaty conglomerate and dark red sandy shale, with a reddish conglomerate, grit and hard, gray sandstone. The paper is accompanied by a map showing the geographical distribution; also a section crossing the district in the vicinity of St .John. In a foot-note mention[5] is made of the discovery of numerous trilobites of two or three species, but they were so excessively distorted that the genera could not be made out.

In some observations on the geology of southern New Brunswick, Prof. L. W. Bailey[6] reprinted the table of formations published by Mr. Matthew in 1863. In a table on page 14 he places the St. John group at the base of the Lower Silurian as an equivalent of the Potsdam or Primordial of New York and the Quebec group of Canada. A full description of the St. John group is given,[7] and accompanying it a letter

[1] On the flora of the Devonian period in northeastern America. Quart. Jour. Geol. Soc. London, vol. 18, 1862, p. 303.

[2] Observations on the geology of St. John County, New Brunswick. Canadian Nat., vol. 8, 1863. p. 243.

[3] Op. cit., p. 242.

[4] Op. cit., p. 244.

[5] Op. cit., p. 247.

[6] Observations on the geology of southern New Brunswick. Fredericton, 1865, p. 8.

[7] Op. cit., pp. 26–31.

from Mr. C. Fred Hartt,[1] in which he states that he has recognized four genera of trilobites from the St. John rocks, viz, Paradoxides, Conocephalites, Agnostus and a new genus (?) allied to Conocephalites. There are also six species of Brachiopods, belonging to the genera Orthisina, Discina, Obolella, and Lingula. Although all of the species are apparently new, the occurrence of Paradoxides and Conocephalites led Mr. Hartt to correlate the entire fauna with the Primordial fauna of Barrande. He states that the lower part of the St. John group, at Coldbrook, has been divided by Mr. Matthew, on lithological grounds, into three bands, viz:

No. 1.—The lower or arenaceous band, with no determinable fossils, and constituting passage beds from the Coldbrook group.

No. 2.—Argillaceous shales, rich in fossils, Paradoxides, Orthisina ?, Conocephalites, Obolella.

No. 3.—Carbonaceous shales, full of fossils, Paradoxides, Conocephalites, Orthisina, Discina, etc., all much distorted.

In the same year Mr. G. F. Matthew described the Azoic rocks of southern New Brunswick.[2] He gave the geographic distribution of the St. John series, and a detailed section of the formation, to which he assigned a total thickness of 4,500 feet. He mentions the identification of the fauna by Prof. Hartt; and refers the St. John group to the Lower Silurian, correlating it with the *Paradoxides harlani* beds of Massachusetts; with the *Paradoxides bennetti* beds of Newfoundland; the Lingula flags of Great Britain; the alum-schists of Scandinavia and "Étage C" of Barrande in Bohemia.[3] He states that the upper portion of the section may be the equivalent of the Calciferous, perhaps the Chazy. The subjacent Coldbrook group is referred to the Huronian, while the terms Cambrian and Huronian are used as synonyms in their application to the Coldbrook formation.[4]

In noticing the discoveries made by Messrs. G. F. Matthew and C. F. Hartt, Dr. J. W. Dawson refers to the correlation made by Prof. Hartt, and proposes to call this series, represented in New Brunswick by the St. John slates, the *Acadian series*.[5] In 1868 he republished all the facts known to him in relation to the St. John group, naming it the Acadian group, and including it under the Lower Silurian.[6] The section given by Mr. Matthew is published, and also descriptions by Mr. C. F. Hartt of all the species discovered by Messrs. Matthew and Hartt in the St. John group.[7]

[1] Preliminary notice of a fauna of the Primordial period in the vicinity of St. John, N. B. Observations on the Geology of southern New Brunswick, 1865, pp. 30, 31.

[2] On the Azoic and Paleozoic rocks of southern New Brunswick. Quar. Jour. Geol. Soc., London, vol. 21, 1865, pp. 422-434, map.

[3] Op. cit., pp. 426, 427.

[4] Op. cit., p. 427.

[5] On recent geological discoveries in the Acadian provinces of British America. Am. Assoc., Proc., vol. 16, 1867, p. 118. Canadian Nat., new series, vol. 3, 1868, pp. 295-297.

[6] Acadian Geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick and Prince Edw. Island, London, 1868, pp. 637-641, 2d ed.

[7] *Op. cit., pp.* 641-657.

In 1869 Messrs. Matthew and Bailey[1] described in a general manner the rocks referred to the Lower Silurian and stated that this series includes about 150 feet of slates (holding Paradoxides, Conocephalites, Agnostus, and other trilobites, besides several genera of Brachiopods), and an overlying mass, measuring not less than 2,000 feet, of flags and slates containing Lingulæ, worm burrows, etc. Under the caption of "Lower Silurian," the same writers, three years later,[2] include the St. John or Acadian group. A brief historical sketch is given, and a list of fossils that have been described from the formation, with a statement that the apparent thickness of the whole formation, as measured in the city of St. John, is about 4,500 feet. Owing to the disturbed condition of the beds the actual thickness may be much less. If repetitions occur, the aggregate thickness of the series, exclusive of the lower red beds—which have been called Upper Coldbrook—will not much exceed 2,000 feet.[3] This general description is followed by a detailed one, and a copy of Mr. Matthew's section at the city of St. John.[4] The St. John group is then described as found in the Kennebecasis Valley, in northern King's County; in Wickham, Queen's County; in Nerepis Valley, and in Charlotte County.

In the supplement to the second edition of Acadian Geology, Dr. J. W. Dawson[5] introduces the term "Cambrian" and includes under it the Acadian series of St. John and also the great Atlantic coast series of Nova Scotia. Nothing is added in the way of descriptive details to those given in the edition of 1868.

During the survey of the island of Cape Breton, Mr. Hugh Fletcher discovered near Marion Bridge, on the banks of the Mira River, a series of light gray, slaty, fine-grained, feldspathic sandstones, associated with red and green mottled sandstone in which he found numerous specimens of Obolella. He points out the lithologic resemblance of these rocks to the Primordial rocks found by Mr. Alexander Murray in the southeastern part of Newfoundland and to those on the Strait of Belle Isle examined by Mr. Richardson.[6] He also describes a series of purple, red, and green slates, sandstones, and limestones, that he refers to the Lower Silurian.[7] A detailed section of the rocks is given as they occur along St. Andrew Channel. In one of the greenish and blue papery slates he found impressions of an Obolella, with the head and tail of a trilobite, recognized by Mr. Billings as of Primordial or Quebec

[1] Remarks on the age and relations of the metamorphic rocks of New Brunswick and Maine. Am. Assoc., Proc., vol. 18, 1869, pp. 182, 183. Can. Nat., new ser., vol. 4, 1869, pp. 326–328.

[2] Preliminary report on the geology of southern New Brunswick. Geol. Surv. Canada, Rep. of Prog., 1870–'71, 1872, p. 134.

[3] Op. cit., p. 135.

[4] Op. cit., pp. 136, 137.

[5] Supplement to the second edition of Acadian Geology, containing additional facts as to the geological structure, fossil remains, and mineral resources of Nova Scotia, New Brunswick, and Prince, Edward Island, London, 1878, p. 81.

[6] Report of explorations and surveys in Cape Breton, Nova Scotia. Geol. Surv. Can., Rep. Prog. 1875–'76, 1877, p. 393.

[7] Op. cit., p. 388.

group age. In his report for the following year he[1] described a number of sections, referring them to the Lower Silurian, and mentioning the occurrence of Lingula, Obolella, and Dictyonema in some of the beds.

In a report on the slate formation in the northern part of Charlotte County, New Brunswick, Mr. G. F. Matthew[2] states that the St. John group occurs in the interval between the Kingston or Upper Silurian rocks and the inclosing Laurentian ridges in King's County. No details are given of the St. John group.

A report on the Primordial-Silurian rocks of New Brunswick by Mr. L. W. Bailey[3] presents a detailed description of the St. John group. A section is given of the strata on Ratcliffe's Mill-stream and Handford Brook and local details of geographic distribution. This is accompanied by a list of the fossils found which were identified by Mr. J. F. Whiteaves.

In a later report on the geology of southern New Brunswick[4] the Cambrian or Primordial Silurian rocks are described as occupying basins or trough-like depressions among the older hills of pre-Cambrian rocks east of the St. John River.

In speaking of the strata carrying the Paradoxides in the vicinity of the city of St. John, Mr. G. F. Matthew[5] states that the strata of the St. John group fill a number of narrow, trough-like basins lying between the Bay of Fundy and the central Carboniferous area of New Brunswick. A carefully measured and detailed section of the St. John outcrop is given with a description of the conditions under which the fossils occur in the same. A thickness of 2,900 feet is assigned to the section.

The same writer argues in a paper on the "Geologic Age of the Acadian Fauna"[6] that on the evidence of the trilobites the St. John group does not quite correspond to the Menevian of Wales, in the restricted application of that term; but, as a whole, they indicate the subjacent Solva group as the equivalent formation to the St. John group. He repeats this correlation a year later,[7] when he says: "Prof. Hartt fixed the age of the St. John group as nearly as was possible in his time

[1] Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Surv. Can., Rep. Prog. for 1876-'77. Montreal, 1878, pp. 429-437.

[2] Report on the slate formations of the northern part of Charlotte County, New Brunswick. Geol. Surv. Canada, Rep. Prog. for 1876-'77. Montreal, 1878, pp. 342, 343.

[3] Report on the pre-Silurian (Huronian) and Cambrian or Primordial Silurian rocks of southern New Brunswick. Geol. Surv. Can., Rep. Prog., 1877-'78, 1879; p. 28DD-34DD.

[4] Bailey, L. W., G. F. Matthew, and R. W. Ells. Report on the geology of southern New Brunswick, embracing the counties of Charlotte, Sunbury, Queens, Kings, St. John, and Albert. Geol. Surv. Can., Rep. Prog., 1878-1879, 1880, pp. 61D-81D.

[5] Illustrations of the fauna of the St. John group. Royal Soc. Canada, Proc. and Trans., vol. 1, sec. iv, 1883, pp. 85-88; pp. 271-279.

[6] The Geologic Age of the Acadian fauna. The Primitive Conocoryphean. British Assoc. Rep., 54th meeting, 1884, pp. 742-743. The Geologic Age of the Acadian Fauna. Geol. Mag., new ser., decade 3, vol. 1, 1884, pp. 470-471.

[7] An outline of recent discoveries in the St. John group. New Brunswick Nat. Hist. Soc. Bull. No. 4, 1885, p. 9o.

as 'Primordial,' or, as we now call it, Cambrian." He then calls attention to the article in which he correlated the St. John group fauna with the Solva group, stating, "In other words, it is the fauna of the older part of the Lower Cambrian."

In a preliminary study of the Cambrian fauna of North America[1] a review is given of the history of the term "St. John group" by Mr. C. D. Walcott. In this the use of "St. John" was advocated as against "Acadian," and all species described by Mr. C. F. Hartt in the second edition of Dawson's Acadian Geology were illustrated.

When discussing the faunas of the St. John group, Mr. Matthew[2] states that it is highly probable that the group covers nearly the whole of the Cambrian age; and that the fauna of the Upper Cambrian is equivalent to that of the shallow-water deposit of the St. John group near the summit of the series. The fauna discovered by Mr. Fletcher in the Cambrian shales of Mira River, Cape Breton Island, is considered by Mr. Matthew[3] to belong to the Olenus division of the Cambrian fauna. The species recognized by him are *Peltura scarabæoides*, *Sphærophthalmus alatus*, and *Agnostus pisiformis*. In the same paper he mentions the faunas of the Olenus division as found in Newfoundland. (An abstract of this paper appeared in the Canadian Record of Science, vol. 2, 1886, pp. 255–258.)

Incited by the announcement of the discovery of fossils beneath the Paradoxides zone in Sweden and Russia, Mr. Matthew[4] began anew the study of the red rocks beneath the Paradoxides zone. These strata had been spoken of as the upper member of the Coldbrook group[5] and as constituting a series lower than the Primordial rocks at the base of the Silurian. They were subsequently joined to the St. John group[6] as the base of that group. In a later report in 1888, Mr. Matthew[7] says: "It is now found that this red series is unconformable, not only to the St. John group, but also (as had been previously discovered) to the underlying Coldbrook group." In the valley of Long Reach of the St. John River Mr. Matthew estimates that the red series has a thickness of 1,200 feet. He compares it with the red shales described by Dr. Murray in Newfoundland[8] and correlates it with the Caerfai group of Wales and the lower division of the Sparagmite formation of Norway.[9] A detailed description of the section is given[10] with names of the fossils that have been found in the various beds. These include trails and casts of marine

[1] On the Cambrian faunas of North America; preliminary studies. U. S. Geological Survey Bull. No. 10, vol. 2, 1884, p. 289, separately paged, p. 9.

[2] Illustrations of the fauna of the St. John group, No. 4, Can. Rec. Sci., vol. 2, 1887, p. 362. (Abstract.)

[3] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada Proc. and Trans., vol. 4, sec. 4, 1887, p. 147.

[4] On a basal series of Cambrian rocks in Acadia. Can. Rec. Sci., vol. 3, 1888, pp. 21-29.

[5] Observations on the geology of southern New Brunswick. Fredericton, 1865, p. 24.

[6] Bailey, L. W., and G. F. Matthew. Preliminary report on the geology of southern New Brunswick. Geol. Surv. Can., Rep. Prog., 1870-'71, 1872, p. 59.

[7] On a basal series of Cambrian rocks in Acadia. Can. Rec. Sci., vol. 3, 1888, p. 22.

[8] Op. cit., p. 23. [9] Op. cit., p. 25. [10] Op. cit., p. 27.

worms, tracks, and an unrecognized brachiopod. This paper was followed in the same year by an article on the classification of the Cambrian rocks of Acadia in which the classification of the Cambrian system in Acadia and Newfoundland is given as follows:[1]

Series A.—The Basal series or Etcminian.
Series B.—The St. John group or Acadian.
Series C.—The Lower Potsdam or Georgian.
Series D.—The Potsdam sandstone and limestone.

The division of series A was noticed in the preceding paper by Mr. Matthew. In series B he includes the zone of Paradoxides; describes the rocks in detail, and gives lists of the genera of the fossils. Series C, the Lower Potsdam of Billings, he states has not been recognized on the mainland of Acadia, but is found in the Island of Cape Breton, where the fossils are Bathyurus, Orthisina, Orthis, *Hyolithes princeps*. This series is placed provisionally above B.[2] Series D, or the Potsdam series of New York and the Mississippi Valley, is stated to be absent from New Brunswick and, as far as known, from the eastern border of the continent.[3]

A reclassification of the Cambrian rocks of North America was published in 1888 by Mr. C. D. Walcott as follows:[4]

TABLE I.—*Lower Silurian (Ordovician) system.*

Subdivisions.	Terranes.	Faunas.
Upper Cambrian	Potsdam, Knox, Tonto, Bell Isle, etc	Dicellocephalus or Olenus.
Middle Cambrian	St. John, Avalon, Braintree	Paradoxides.
Lower Cambrian	Georgia, Prospect, Terra Nova	Olenellus.

This is followed by a comparison of typical sections of the Cambrian system in Sweden, Newfoundland, New York, and the Rocky Mountains. The section on Manuel's Brook, Conception Bay, Newfoundland, where the true stratigraphic succession of the Cambrian deposits in America was first discovered, is given in detail.

On learning of the discovery of the Olenellus fauna beneath the Paradoxides zone in Newfoundland, Mr. Matthew published a second paper "On the classification of the Cambrian rocks in Acadia," in which he arranged the Cambrian system as it occurs in Acadia as follows:[5]

	Localities.
D. Upper Cambrian (Potsdam series)	Unknown.
C. Middle and Lower Cambrian—Acadian series	St. John, etc.
B. Lower Cambrian—Georgian series	Cape Breton.
A. Basal Cambrian—Etcheminian series	St. John, etc.

[1] Matthew, G. F. On the classification of the Cambrian rocks of Acadia. Can. Rec. Sci., vol. 3, 1888, p. 72.
[2] Op. cit., pp. 73–74. [3] Op. cit., p. 80.
[4] *The stratigraphical succession of the Cambrian faunas in North America.* Nature, vol. 38, 1888, *p. 551.*
[5] *On the classification of the Cambrian rocks in Acadia.* No. 2. Can. Rec. Sci., vol. 3, 1889, p. 210.

Instituting comparisons between the sections of Sweden and New Brunswick, he discusses the general relations of the Cambrian fauna of North America. The organic remains found in band B are an Agraulos, and at the base of the zone an Ellipsocephalus, of the type associated with *Olenellus* (?) *kjerulfi* in Europe. At the base of band B he found a species of Obolus which he described as *Obolus pulcher*.[1] This comprises the Lower Cambrian fauna or pre-Paradoxides fauna as known to him from New Brunswick up to date.

In another paper on the "Cambrian organisms in Acadia," published in the same year, he notes the discovery in the lower beds of the St. John section, beneath the Paradoxides beds, of several varieties of sponges, a species of Palæochorda and another undescribed species. Undoubted examples of Platysolenites of Pander also occur.[2] Mention is made of the discovery above the Paradoxides zone in the Olenus horizon, of three species of fossils, and above this another stage which he has placed under the title of Peltura beds, corresponding in age to the Cape Breton Upper Cambrian beds.

In September, 1889, Mr. Matthew[3] argues for the uniting of the Olenellus or Lower Cambrian, and the Paradoxides or Menevian zone, as one division of the Cambrian, and the strata above the Paradoxides zone as the upper division, thus returning to the classification of Salter and Hicks, adopted for the Cambrian strata of Wales.

The full text of Mr. Matthew's paper on the Cambrian organisms in Acadia was distributed in June, 1890. It deals almost entirely with the pre-Paradoxides or Basal series of the Cambrian section of New Brunswick, and is accompanied by both tabulated and illustrated sections and sketch maps of Hanford Brook and Caton's Island.[4] It is referred to at length in the description of the Cambrian rocks of New Brunswick in this paper (Chapter. IV).

In a paper read May 28, 1890, Mr. G. F. Matthew gives a detailed description of the geologic structure of the St. John basin in connection with three sections crossing it. Further notice of it will be found in the summary of our present knowledge of the St. John terrane of New Brunswick.[5]

In a list of the geological formations of the Maritime Provinces of Canada, Dr. George M. Dawson tabulates the Cambrian as follows:[6]

2*c*. Upper Cambrian	Miré and St. Andrew series. Cape Breton.
2*b*. Middle Cambrian	Acadian series.
2*a*. Lower Cambrian	Atlantic Coast series. Nova Scotia.

[1] Op. cit., p. 306.

[2] On the Cambrian organisms in Acadia. Can. Rec. Sci., vol. 3, 1889, p. 384.

[3] How is the Cambrian divided? A plea for the classification of Salter and Hicks. Am. Geol., vol. 4, 1889, pp. 139–148.

[4] On Cambrian organisms in Acadia. Trans. Roy. Soc. Can., vol. 7, sec. 4, 1890, pp. 138–143.

[5] Matthew, G. F. Illustrations of the fauna of the St. John group, No. 5. Trans. Roy. Soc. of Canada, vol. 8, sec. 4, 1891, pp. 123–130, pls. II–XVI.

[6] An American Geological Railway Guide. James McFarlane. 2d ed., 1890, p. 52.

MAINE.

When describing the quartz rock of Bar Harbor, Mount Desert Island, Prof. C. H. Hitchcock[1] suggested a Lower Silurian age for the siliceous slates associated with the coarse sandstone or quartz rock, by comparison with similar rocks on Flint Island, of which he had stated that the correlation was more from fancy than real argument, because it reminded him so much of the Potsdam sandstone in its external appearance.

At a later date he says:[2]

> The first rock is a sandstone at Bar Harbor, dipping at an angle of twelve degrees. Ripple marks cover the surface of many layers, and curious cylindrical stems tantalize us by their resemblance to fossils. The formation is probably of Cambrian age.

The strata included under the title of "Cambrian" about Portland, Maine, is described by Prof. Hitchcock[3] as follows:

> These rocks crop out in Saco, a dozen miles west. They are clay slates and indurated argillaceous schists, the latter having a northwest strike, while the rocks of the older series run northeasterly. These rocks are in character and position allied to the Cambrian Paradoxides slates of Massachusetts, and exist in immense mass along the coast of Maine west of Saco, and in New Hampshire.

The correlation of these beds is based entirely upon their lithological characters, as no mention is made of any fossils having been found in them.

In his account of the geology about Frenchman's Bay, on the coast of Maine, Dr. W. O. Crosby describes the slate formation. The prevailing rock is a compact and well jointed argillite or clay slate, of black, drab, and purple tints, with distinct stratification. The author concluded that these rocks are the newest rocks on this part of the coast, by their relations in dip and distribution to the present contours of the land; by their uncrystalline character; by their relations to the intrusives; by the fossils which they contain. The latter he describes as smoothly and even gracefully curved semi-cylindrical grooves and ridges about a line in diameter; they are often a foot or two in length, and might sometimes be regarded as annelid trails, but in other cases they are irregularly branched in a way that would be impossible with worm-grooves, but is very suggestive of smooth, slender fucoids.[4] The general conclusion reached was that the Frenchman's Bay series belonged somewhere between the top and bottom of the Cambrian, with the chances in favor of its being near the latter. In other words, his observations tended to corroborate the suggestion made by Prof. Hitchcock twenty years before. He further states:

---

[1] Reports on the Geology of Maine. Second annual report on the natural history and geology of Maine. Augusta, 1862, pp. 269–271.

[2] Geology of New Hampshire. Concord, 1877, vol. 2, p. 32.

[3] The geology of Portland. Am. Assoc. Proc., vol. 22, pt. 2, 1873, p. 168.

[4] Geology of Frenchman's Bay, Maine. Boston Soc. Nat. Hist., Proc., vol. 21, 1881, pp. 111–116. Geol. of Frenchman's Bay, Maine, just east of Mount Desert Island. Am. Jour. Sci., 3d ser., vol. 23, 1882, p. 64.

The resemblance of these rocks to the Acadian slates of the Boston Basin and St. John is very marked; and I join with Prof. Hitchcock in anticipating the discovery on the Maine coast of characteristic Primordial fossils.[1]

In describing a geologic map of Maine, Prof. Hitchcock says that he is unable to divide the Cambrian and Huronian, owing to a want of knowledge of their distribution.

They are the talcose and mica schists of the reports, called the Quebec group by H. Y. Hind and Sir W. E. Logan; the St. John's group in New Brunswick, and the Merrimack, Rockingham, Kearsage, Andalusite, and Coös groups of the New Hampshire reports. * * * They were called Cambrian in New Brunswick by Gesner, and in our second report it was said that this term might ultimately express their true age. Subsequently Bailey and Matthew referred them to the Lower Devonian but the drift of opinion is towards the earlier view at present.[2]

On the map it is very difficult to make out the distribution, owing to the color of the Laurentian, Silurian, and the Cambrian being apparently identical. The supposed Cambrian rocks of New Hampshire and southeastern Canada follow up the valley of the St. John River from a little distance above the entrance of the Allegosh River, and along the Canadian boundary line nearly to the boundary of New Hampshire. The Canadian extension of these rocks is described more in detail and will be mentioned under the head of the Canadian Extension of the Northern Appalachian District (Chapter IV).

In the latest contribution that we have upon the subject of the geological age of the siliceous slate and associated sandstones or quartz rocks of Mount Desert, Maine, Prof. Shaler says:[3]

We note in the first place that there is a total absence of limestones in all the sections exposed to view. A careful study of the drift materials on the south part of Mount Desert and on the Cranberry Islands where we could hope to find traces of hidden limestones shows that there are no limy beds in the sedimentary deposits of this island. The aggregate thickness of the various Mount Desert sections can not be less than about 6,000 feet and may amount to one-half more than this estimate. It seems as if this fact must exclude the hypothesis that these strata were formed anywhere in the periods above the level of the Cambrian, for nowhere above that level do we have any such sections barren of limy matter.

It may be next noted respecting the schistose series of Mount Desert that those of its east and west margins are of singularly uniform composition. They were doubtless originally shales and thin sandstones of great uniformity of structure. Their texture is not such as at all points to exclude the preservation of fossils; indeed the greater portion of the deposits are well fitted to exhibit organic remains, yet they have afforded no trace of them. Nowhere above the level of the Cambrian series do we find any section of this description. On these grounds, it seems reasonable to place the greater part of the Mount Desert rocks in the lower portion of the Cambrian section, if not yet lower in the geological column.

This coincides with the views of Hitchcock and Crosby, that the strata under consideration are of pre-Silurian and probably of Cambrian age.

---

[1] Op. cit., p. 117.

[2] Geological map of Maine (with notes on geology of). In Geology of Northern New England, 1885, p. 2.

[3] The geology of the island of Mount Desert, Maine. Eighth Ann. Rep. U. S. Geol. Survey, pt. 2, 1889, p. 1059.

NEW HAMPSHIRE.

In the final report of the geology and mineralogy of New Hampshire, Dr. C. T. Jackson describes the Cambrian system as understood by him at that time, and states that metamorphic Cambrian rocks occur in New Hampshire, but they contain no fossils. He also says:

The oldest transition, or Cambrian rocks, occur in Maine and Vermont, and dip in opposite directions, indicating an anticlinal axis in New Hampshire.

On the eastern side of this axis we discover the first distinct fossils in the slate strata on the Kennebec River, where the strata dip boldly to the northwestward.

On the western side we have not yet determined the limits of the Cambrian fossils, but indistinct remains of organic substances, whose nature is problematical, occur in the neighborhood of Castleton, and along the western flank of the Green Mountains. They were supposed by Dr. Carr, who first noticed them, to be graptolites, which are supposed to be allied to sea-pens. Graptolites are described by Murchison as belonging to the lower part of the Silurian system. He states, however, that these pen-like serrated fossils have a great vertical range in the older or protozoic rocks, being found from the lower part of the Ludlow formation down to very ancient beds in the Cambrian system.

Should these fossils prove to be graptolites, they would indicate the proximate limits of the Cambrian rocks on the western side of the New Hampshire anticlinal axis, where the strata dip to the southeastward.

It will be observed that the strata become more and more recent as we proceed eastward and westward from this axis, as is proved by order of superposition, lithological characters and fossil contents of the rocks.[1]

Prof. Hitchcock says[2] that the term Cambrian is misapplied by Dr. Jackson, and the ideal section showing the structural geology is incorrect in many of its details. In the final report of the second geological survey of New Hampshire he describes the Rockingham mica-schist as an uncouth mica-schist. The Merrimack group is a micaceous quartzite that has not yet been fully separated from the previous group. It abounds in beds of coarse, indigenous granite, which seem to have been altered in situ from the feldspathic conglomerate. In certain parts of Strafford County the granite beds predominate, forming numerous hills, while the slate occupies the valleys between.[3] Some schists with interbedded clay slates which are referred to the Merrimack group, are supposed to be equivalent to the Paradoxides beds of Massachusetts.

The Connecticut Coös period can easily be divided into three parts: first, the epoch of the deposition of the mountain masses of silica; second, of hornblende and mica schists; third, of limestone.[4]

In the White Mountain region there are several small areas of andalusite slate, supposed to be the equivalent of the Coös group. * * * * The Coös period was terminated by eruptions of syenitic granite. * * * * The Coös quartzite now constitutes a distinct range of mountains.[5]

The Mount Mote conglomerate is formed of an eruption of igneous material cementing together the slaty fragments. This is included in the

[1] Final report on the geology and mineralogy of the State of New Hampshire, with contributions towards the improvement of agriculture and metallurgy. Concord, 1844, p. 14.

[2] History of the Geological Surveys in New Hampshire. Geology of New Hampshire, vol. 1, 1874, p. 11.

[3] *Physical history* of New Hampshire. Geology of New Hampshire, Concord, 1874, vol. 1, p. 536.

[4] *Op. cit.*, p. 537. [5] Op. cit., p. 538.

section between the Huronian and the Helderberg period. On the map facing page 536 the formations referred to the mica-schist period are clearly outlined. In a subsequent paper Prof. Hitchcock[1] presented a table or scheme representing the stratigraphical column of New Hampshire. The Cambrian includes at the summit the Rockingham schists, and below, in order, the calciferous mica-schist, the Coös group, clay slates, and Mount Mote conglomerate. The description of the various formations is given on page 13 and on the map the geographic distribution is delineated. This paper appears to have been prepared and published prior to the issue of the second volume of the Geology of New Hampshire[2] and it does not refer to the volume. On page 674 of the latter work the formations in New Hampshire are tabulated as follows:

		Feet.
Paleozoic.	Upper Helderberg (Vermont) 200; Lower Helderberg, 500	700
	Calciferous mica schist	4,800
	Coös group. Staurolite slate	3,000
	Coös group. Mica schist, often stauroliferous	3,300
	Coös group. Quartzite	1,000
	Cambrian slates (Connecticut Valley)	3,000
	Total Paleozoic	15,800
Paleozoic?	Kearsarge andalusite group	1,300
	Rockingham mica-schist	6,000
	Merrimack group	4,300
	Ferruginous slates, with steatite (probably repetition of preceding)	
	Total Paleozoic?	11,600

Under the head of Cambrian, in the Geology of Northern New England, Prof. Hitchcock says:[3]

The discussions about the value of the Cambrian series are leading geologists to assign to this place in the column a thick mass of sediment, usually without fossils and largely argillaceous in character. We may for the present place here the following groups: (1) Mica-schists of southern New Hampshire. (2) Merrimack group, including argillo-quartzites in Coös County. (3) Coös group. (4) Clay slates. (5) Mount Mote conglomerates.

In one of his later papers, Prof. Hitchcock,[4] in speaking of the various formations that make up the mica-schist group, says they may be called Silurian, Cambrian, or pre-Cambrian, according as each author is inclined to regard New England as very ancient or on the verge of the Paleozoic. In a table giving the thickness of the formations[5] the Cambrian slate series has a thickness of 4,000 feet; and beneath it

[1] Geological map of New Hampshire and Vermont, with notes on topography and geology. In Geology of Northern New England, 1874, p. 9.

[2] Hitchcock, C. H. Geology of New Hampshire, Concord, 1877, vol. 2.

[3] Geological map of New Hampshire and Vermont, with notes on topography and geology. In Geology of Northern New England, 1874, p. 13.

[4] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, p. 168.

[5] Op. cit., pp. 178, 179.

we find the Crystalline group that was referred to the Cambrian in the Geology of Northern New England in 1874, as follows:

Crystalline group.

	Feet.
Calciferous mica-schist and Coös group	12,000
Kearsarge group	1,300
Rockingham mica-schist	6,000
Merrimack group	4,300

Beneath the Merrimack group the Huronian is placed, with a thickness of 12,000 feet.

In a tabulation of the geological formations of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, by Prof. Hitchcock,[1] the calciferous mica-schist, staurolite slate and schists, quartzite, andalusite schists, and Rockingham mica-schists are included in the Cambrian. In a foot-note he says that the quartzite, staurolite slate and schist, and the calciferous mica-schists may yet prove to be Silurian. In his classification of the Paleozoic rocks of New England he places under Cambrian the St. John or Braintree slate, Taconic slate, and Roxbury conglomerate.

In a table published in 1890 he includes only the Potsdam, Georgia, Acadian, and the Taconic slate (in part) in the Cambrian. All of the foliated crystalline rocks of New England are classified as pre-Cambrian.[2]

EASTERN MASSACHUSETTS.

The references to the argillite and limestone in which the Cambrian faunas have been found, in the Boston and Narragansett Basins, occur in most of the publications relating to the geology of eastern Massachusetts. In 1818 Messrs. J. F. and S. L. Dana stated that the argillite was the oldest rock known in the region.[3] Its distribution is shown in a general way upon the map accompanying the report. It is stated to be subjacent to the syenite in Milton and Braintree, and to be stratified. In the works of Prof. Amos Eaton[4] the rocks of eastern Massachusetts are shown in sections, but nothing is added to the data given by the Messrs. Dana.

The next description of the geology of Boston and vicinity, by Dr. J. W. Webster,[5] mentions that the light gray clay slate is the only rock found on the Boston Peninsula in situ. He noticed the presence of the slate in Quincy and also at Naliant.

[1] Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, p. 56.

[2] Idem., second edition, 1890, p. 86.

[3] Outlines of the mineralogy and geology of Boston and its vicinity, with a geological map. Am. Acad. Arts and Sciences, Memoirs, vol. 4, 1818, pp. 129–223.

[4] An Index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 52. A Geological and Agricultural Survey of the District Adjoining the Erie Canal, Albany, 1824, pp. 163, plate.

[5] Remarks on the geology of Boston and its vicinity. Boston Jour. Phil. and Arts, vol. 2, 1824, pp. 277–292.

In 1832 Prof. Edward Hitchcock[1] described the argillite in the vicinity of Boston, and stated that the unstratified rocks were of igneous origin and intrusive among the stratified rocks. A general description of the argillite is given in the text with localities, and on the map the geographic distribution, as known to him, is delineated. This includes the Quincy locality. In the final report of the Massachusetts survey Dr. Edward Hitchcock, in speaking of the argillaceous slate of the eastern part of the State, says that owing to its intimate connection with varieties of rock referred to the Graywacke group it ought to be described as one of the members of it, although marked as a distinct deposit on the map. He considered this slate as older than the graywacke, because fragments of the slate occur in one of the varieties of conglomerate of the graywacke.[2] On the same page, in describing the limestone in the southwest part of Attleborough, he says small beds of compact light gray limestone occasion the red sandrock. He did not see much of it in place, but the numerous blocks in the stone walls indicated its existence in that locality. On the map accompanying the report the argillaceous slate is shown in eastern Braintree, the central part of Quincy, and thence extends across Milton and Dorchester to Roxbury. A small outcrop is also indicated on the north side of Nahant. The North Attleborough locality of the Cambrian as now known is covered by the Carboniferous (No. 17 of the legend of the map). The description in the report of 1841 is essentially the same as in the preliminary report of 1833.

In an article on the crystalline limestones of North America Dr. T. S. Hunt[3] suggests that the limestones interstratified with the red slates at Attleborough, as described by Dr. Hitchcock, may correspond to those which with similar slate and sandstone are met with at the base of the Carboniferous formation in Canada and in New Brunswick.

The long silence in relation to the geologic age of the altered rocks of eastern Massachusetts in the vicinity of Braintree was finally broken in 1856 by the announcement of Prof. W. B. Rogers that trilobites of the genus Paradoxides had been discovered at a quarry in a belt of siliceous and argillaceous slate lying on the boundary of Quincy and Braintree, about 10 miles south of Boston. In announcing this discovery he compares the species found with *Paradoxides spinosus* of Barrande. He states:[4]

> The rock in which these fossils occur is a compact, dense, rather fine-grained, silico-argillaceous slate or slaty sandstone, containing little or no carbonate of lime. * * * * * One of the most curious facts relating to the trilobite of the Quincy and Braintree belt is its seeming identity with *Paradoxides harlani*, described by Green in his Monograph of North American Trilobites.

[1] Report on the geology of Massachusetts, examined under the direction of the government of that State during the years 1830 and 1831. Am. Jour. Sci., vol. 22, 1832, pp. 1-70, with map.

[2] Final report on the geology of Massachusetts, 1841, vol. 2, p. 537, Amherst.

[3] Am. Jour. Sci., 2d ser., vol. 18, 1854, p. 199.

[4] Proofs of the Protozoic age of some of the altered rocks of eastern Massachusetts from fossils recently discovered. Am. Acad. Proc., vol. 3, 1856, p. 317.

He adds further:

The occurrence of well preserved fossils among rocks so highly altered and so contiguous to great igneous masses as are the fossiliferous slates of Quincy may well encourage us to make careful search in other parts of New England where heretofore such an exploration would have been deemed useless.[1]

Prof. Louis Agassiz, in commenting upon the announcement of Prof. Rogers, said that, geologically speaking, its importance could hardly be overestimated. We have now, he remarked, a standard level upon which to build up the formation of the metamorphic rocks.[2] Prof. Rogers also communicated the knowledge of the discovery of the Braintree fossils to Prof. J. D. Dana, in a letter dated August 13, 1856.[3] He states that his attention was called to the locality by Peter Wainwright, Esq., who resided in the vicinity of the quarry.

Dr. Isaac Lea[4] visited the Braintree quarry, and in reporting upon it to the Philadelphia Academy of Natural Sciences stated that he agreed with Prof. Rogers in placing this formation among the more ancient of the Paleozoic periods. "It lies directly on the granite rocks, or rather it is squeezed in, and is embraced by these rocks (on the east and west sides), which are disturbed by an upheaval." He considered the trilobite found there to be undoubtedly the same as described by Prof. Green many years before under the name of *Paradoxides harlani*.

Prof. W. B. Rogers again called attention to the Braintree locality[5] for the purpose of noting the fact that the formation was among the oldest of the Paleozoic series, and situated somewhere about the level of the Primal rocks (Potsdam sandstone and the Protozoic sandstone of Dr. D. D. Owen), containing Dikellocephalus in Wisconsin and Minnesota.

In 1856 Prof. C. T. Jackson[6] described the rock at Braintree as a blue gray, argillaceous slate, containing silicate of lime but no carbonate, and some disseminated iron pyrites. The stratification of the rock, as indicated by its grain and cleavage, dips to the north 50°, and runs east and west. The existence of the genus Paradoxides in the argillaceous slates of Braintree, proves them to belong to the lowest of the fossiliferous Silurian rocks, and he believed them to be the geological equivalents of the argillaceous slates of Sweden, which are in a similar manner disrupted by the intrusion of syenite.

---

[1] Am. Acad., Proc., vol. 3, 1856, p. 318. [2] Ibid., p. 319.

[3] Discovery of Paleozoic fossils in eastern Massachusetts. Am. Jour. Sci., 2d ser., vol. 22, 1856, pp. 296-298.

[4] [On the trilobite formation at Braintree, Massachusetts.] Phila. Acad. Sci., Proc., vol. 9, 1858, p. 205.

[5] [On trilobites from Braintree and on the geologic relations of the district.] Boston Soc. Nat. Hist., Proc., vol. 6, 1856, pp. 27-29, 40, 41.

[6] [On the Braintree argillite and its trilobites.] Boston Soc. Nat. Hist., Proc., vol. 6, 1856, pp. 42-44.

In arranging the collections of the State cabinet of Massachusetts, Dr. Edward Hitchcock placed the rock near Boston which carries the trilobites in the Silurian and Cambrian.[1]

Prof. W. B. Rogers sent to Mons. J. Barrande[2] a photograph of the Paradoxides found at Braintree. Barrande compared it with *Paradoxides spinosus* and concluded that *Paradoxides harlani* was a synonym of *Paradoxides spinosus*.

In 1861 Prof. Rogers[3] announced the discovery by Mr. Norman Easton of pebbles carrying fossils of the Potsdam fauna in Carboniferous conglomerate north of Fall River, Massachusetts. He thought the forms distinctly recognized in the pebbles were Lingula of two species, resembling *Lingula prima* and *L. antiqua* of Emmons, from the Potsdam sandstone of New York, and that the rocks from which the pebbles were derived were probably closely connected in time with the period of the Braintree Paradoxides beds. The conglomerate in which the pebbles occur is considered to be of Carboniferous age.

Various communications were made to the Boston Society of Natural History respecting the Paradoxides fauna at Braintree, by Messrs. Jules Marcou and C. T. Jackson in 1861 and 1862. From that time until 1869 little attention appears to have been given to the Braintree rocks. In the latter year Prof. N. S. Shaler[4] described the rocks in the vicinity of Boston, and referred to the argillites of Braintree, stating that they were deposited in deep water. In 1870 Dr. T. S. Hunt examined the rocks near Braintree, and stated that the unaltered argillites of Braintree, holding the Primordial fauna, were observed by Prof. Shaler and himself to rest directly upon a hard porphyrite felsite of the ancient series. He says:[5]

> The fact that the Primordial strata of Braintree have suffered no metamorphism is the more significant, since the beds of similar age in New Brunswick and Newfoundland rest unconformably on crystalline strata supposed to belong to the same ancient series that underlies the Braintree beds, and are, like these, unaltered sand and mud rocks.

In 1875 Mr. W. W. Dodge[6] described the rocks at and about Braintree in the Boston Basin with great detail, and accompanied this with a discussion of the correlation of the Paradoxides beds with the various lower Paleozoic rocks of Europe.

In the same year, in some remarks on Massachusetts geology, Dr. T. S. Hunt[7] reaffirms his observation on the relations of the fossiliferous

---

[1] [Catalogue of State cabinet and notes on metamorphic rocks] 6th annual report of the Secretary of Massachusetts Board of Agriculture, etc., by Charles L. Flint, Boston, 1859, p. iv.

[2] Trilobiten der Primordial-fauna in Massachusetts. Neues Jahrb. für Mineral., 1860., pp. 429–431.

[3] On fossiliferous pebbles of Potsdam rocks in Carboniferous conglomerate north of Fall River, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 7, 1861, pp. 389–391.

[4] On the relations of the rocks in the vicinity of Boston. Boston Soc. Nat. Hist., Proc., vol 13, 1869, pp. 172–178.

[5] On the geology of the vicinity of Boston. Boston Soc. Nat. Hist., Proc., vol. 14, 1871, p. 48.

[6] Notes on the geology of eastern Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 17, 1875, pp. 388–419.

[7] [Remarks on Massachusetts geology.] Boston Soc. Nat. Hist., Proc., vol. 17, 1875, pp. 508–510.

rocks of Braintree and St. John, New Brunswick, to the subjacent crystalline Huronian strata.

The following year Prof. W. O. Crosby described the Geological Map of Massachusetts, and said:[1]

> Although the fossils characteristic of the Acadian group have been found at only one locality in Massachusetts, viz, Hayward's quarry, in Braintree, yet most observers agree that the greater portion of the slates in the vicinity of Boston are probably of Primordial age; and I have so represented them on the map.

The strata referred to are then described in a general way.

In 1875 Prof. W. B. Rogers[2] announced the discovery of impressions suggestive of the fossil Lingula mentioned by him from Fall River, in pebbles of the conglomerate, at Newport, Rhode Island. The pebbles consist of a gray siliceous rock or quartzite.

The memoir of Prof. W. O. Crosby on the Geology of eastern Massachusetts, with its accompanying map, appeared in 1880. He says:[3]

> The Paleozoic rocks of eastern Massachusetts occur, as already indicated, only in limited basins or depressions excavated in the ancient crystalline formations. . . .
>
> The most diligent search, continued for many years, by, in the aggregate, a small army of observers, has failed to bring to light, among the rocks of the Boston Basin, more than one locality affording fossils. This is the celebrated slate quarry of the south shore of Hayward's Creek, in the extreme northeast corner of Braintree.

Prof. Crosby[4] concludes that the Paradoxides bed in Braintree is the established base line for the stratigraphy of the Boston Basin; and that all the rocks in the Boston Basin above the Shawmut group, and including the Paradoxides bed, belong to one and the same essentially conformable series; although (p. 186) there is in the Boston Basin essentially but one conglomerate and one slate, and the former underlies the latter. From this it follows that the slate is of Primordial age, and the conglomerate must be of the same age, or older. The conglomerate is stated to pass gradually into the slate, and a detailed description of these two formations is given as they occur in the Boston Basin. On the map a part of Nahant is colored to indicate the Cambrian slate. In the text he describes white and gray limestones that in texture are very compact and highly crystalline or saccharoidal. These have a thickness collectively of perhaps 20 feet. He assigns to the conglomerate a maximum volume not exceeding 1,000 feet; and considers that the greatest thickness of the slates cannot be much less than that of the conglomerate, though in some cases falling below 500 feet.[5]

Dr. M. E. Wadsworth,[6] in discussing the relation of the Quincy granite to the Primordial argillite of Braintree, states that Dr. Hunt was

---

[1] Report on the geological map of Massachusetts, Boston, 1876, p. 40.

[2] On the Newport conglomerate. Boston Soc. Nat. Hist., Proc., vol. 18, 1875, p. 100.

[3] Contributions to the geology of eastern Massachusetts. Boston Soc. Nat. Hist., Occasional papers, No. 3, 1880, p. 181, 183.

[4] Op. cit., pp. 184, 185. [5] Op. cit., p. 266.

[6] On the relation of the Quincy granite to the Primordial argillite of Braintree, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 21, pp. 274–277, 1882.

mistaken in regarding the granite as of Huronian age, as was Prof. Shaler in regarding it as a metamorphosed sedimentary rock. He says the argillite is surrounded by intrusive granite of a later age, thus adopting the view advanced by Dr. Hitchcock in 1832. In describing the slates, he says they dip a little west of south at an angle of 55°, nearly as given by Mr. Lea. He thinks that, judging from their writings, Profs. Rogers and Shaler based their conclusions regarding the dip of the argillite upon its structural character. In another paper, published the following year, Dr. Wadsworth discusses the argillite and conglomerate of the Boston Basin,[1] and concludes from studies made by him that there are at least two distinct argillites. One like that underlying the conglomerate on Beacon street, Boston, and resembling in some of its characters the Paradoxides argillite at Braintree. The second is of coarser grain, often more decidedly arenaceous, and generally of a gray, black, or reddish color, and forms the Somerville argillites ("Cambridge slates.") It is stated:[2]

> So far as we have any evidence at present the oldest surface rocks in this basin are the argillites and the schists of allied character. Of these we only know the age of a very small area in Braintree and Quincy. * * * Older rocks than the Braintree (Paradoxides) argillites may exist, but of their existence we thus far have no proof.

The discovery of fossils of Lower Cambrian age near North Attleborough, Bristol County, Massachusetts, by Prof. N. S. Shaler,[3] located a second area of Cambrian rocks in eastern Massachusetts. He describes the geographic distribution and the character of the rocks, and in an accompanying paper in connection with Mr. A. F. Foerste gives a description of the fauna. As the description of the strata and the fauna is that which is given in our summary of the present knowledge of the rocks of eastern Massachusetts, it is here omitted.

In a review of the stratigraphic position of the Olenellus fauna by Mr. C. D. Walcott in 1889,[4] it is shown that the Paradoxides fauna of Braintree, Massachusetts, of St. John, New Brunswick, and of southeastern Newfoundland, is superjacent to the Olenellus fauna, and thus above the Olenellus fauna as found at North Attleborough by Prof. Shaler. This is presented more fully in a paper in the Tenth Annual Report of the Director of the U. S. Geological Survey.[5]

In a sketch of the physical history of the Boston Basin, Prof. W. O. Crosby[6] mentions the old and more or less altered or metamorphic slates of the Braintree quarry, and states it to be clearly established that the

[1] The argillite and conglomerate of the Boston Basin. Boston Soc. Nat. Hist., Proc., vol. 22, 1883, pp. 130–133.

[2] Op. cit., pp. 132, 133.

[3] On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zoöl. Harv. College, vol. 16, 1888, pp. 13–26.

[4] Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 374–392; vol. 38, 1889, pp. 29–42.

[5] The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geological Survey, 1890, pp. 509–763, plates 49–98.

[6] Physical History of the Boston Basin. Lowell free lectures, 1889–1890. Boston, 1889, pp. 22.

granite is eruptive through, and therefore newer than the Primordial slate. The evidence of the trilobites shows that the slates were formed very far back in geological time, and near the base of the recognized geological formations. In a résumé of the geological history of the Boston Basin,[1] a general description of the Primordial slates and quartzites and their physical relations is given.

In mentioning the discovery of fossils in the limestones at Nahant, Mr. A. F. Foerste correlated the Nahant limestone with the red slates of North Weymouth, and concluded that they are stratigraphically beneath the Braintree Paradoxides beds, and that the red slates of Mill Cove at North Weymouth are of Olenellus age and beneath the Paradoxides strata.[2]

In 1889 Mr. A. C. Lane described the geology of Nahant from a mineralogical standpoint,[3] and in the following year Prof. J. H. Scarp published a description of the stratified rocks of Essex County, which includes the limestones and associated slates of Nahant. He mentions finding *Hyolithes princeps*, *Hyolithes communis* var. *emmonsi*, *Hyolithes impar*, and *Stenotheca rugosa*.[4] He also discovered an outcrop of the Lower Cambrian limestone in a valley between Prospect Hill and Hunslow's Hill, in Rowley, in which fragments of Hyolithes occur.

PALEONTOLOGY.

NEWFOUNDLAND.

The first announcement of the discovery of the Cambrian fauna in Newfoundland appears to be by Mr. J. W. Salter[5] in the description of *Paradoxides bennettii*. He referred the species to the "Lingula flags or Zone Primordiale."

From collections made by the Canadian Geological Survey Mr. E. Billings described in 1861[6] the fauna from the Cambrian strata on the north side of the Straits of Belle Isle, on the Labrador shore, at L'Anse au Loup, and assigned it to the horizon of the "Lower Potsdam," correlating it with the fauna found in Franklin County, Vermont, which is described in the same paper. The species described are *Palæophycus incipiens*, *Archæocyathus atlanticus*, *Obolus labradoricus*, *Obolella chromatica*, *O.* (*Kutorgina*) *cingulata*, *Conocephalites miser*, *Bathyurus senectus*, *B. parvulus*, *Salterella rugosa*, *S. pulchella*, and *S. obtusa*. The new

[1] Op. cit., pp. 19–22.

[2] The Paleontological horizon of the limestone at Nahant, Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 261–263.

[3] Geology of Nahant. Boston Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 91–95.

[4] The stratified rocks of Essex County. Essex Institute Bull., vol. 22, 1890, p. 32.

[5] On the fossils of the Lingula flags or "Zone Primordiale." Quar. Jour. Geol. Soc., London, vol. 15, 1859, p. 552.

[6] Paleozoic Fossils, vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860–1865. Montreal, 1865, pp. 426. (Of this volume pp. *1–24* were issued in November, 1861; pp. 25–56 issued January, 1862; pp. 57–168 issued June, 1862; pp. *169–344* issued February, 1865; pp. 395–416 published in Canadian Naturalist, vol. 5, 1860, pp. 301–324.)

genera are Archæocyathus, Obolella, Kutorgina, and Salterella. In reprinting, in 1865, the article published in 1861, Mr. Billings added a new species, *Archæocyathus profundus*; and in the same year described *Acrotreta gemma* from near Portland Creek.

The mode of occurrence of the Cambrian section and fauna on the northwest coast of Newfoundland is given by Sir William Logan in the description of the geological section near Bonne Bay.[1]

From a collection of fossils from Newfoundland sent by Mr. Alexander Murray to Mr. E. Billings, there was described in 1865 *Bathyurus gregarius*=*Solenopleura gregarius* from the Paradoxides horizon of southeast Newfoundland.[2] Subsequently he[3] described the fauna found at Great Bell Island and also "Fossils from the Menevian Group," under which we find *Obolella? miser*, *Straparollina remota*, *Hyolithes excellens*, *Agraulos socialis*, *A. strenuus*, *A. affinis*, *Solenopleura communis*, *Anopolenus venustus*, *Paradoxides tenellus*, *P. decorus*, *Iphidea*, n.gen., *Iphidea bella*, *Stenotheca pauper*, *Scenella*, n. gen., *Scenella reticulata*. Also from the shales and sandstones of Great Bell Island, Conception Bay: *Eophyton linnæanum*, *E. jukesi*, *Arthraria antiquata*, *Lingula murrayi*, *Lingulella* (?) *affinis*, *L.* (?) *spissa*, and *Cruziana similis*.

With the exception of *Obolella? miser*, *Solenopleu ra communis*, *Steno theca pauper*, and *Scenella reticulata* the species described in 1872 were republished in the appendix to the report of progress of the Geological Survey of Newfoundland for 1881.

In 1878 Mr. J. F. Whiteaves described[4] a new species of Lingula, *L. billingsiana*, from the shales of Kelley's Island, and republished Murray's geological section on Manuel's Brook, southeast Newfoundland, with a list of fossils collected there as follows: 1. *Agnostus acadicus*; 2. *Agnostus* (sp. undet.); 3. *Microdiscus punctatus*; 4. *M. dawsoni*; 5. *Conocephalites tener*; 6. *C. baileyi*; 7. *C. orestes?*; 8. *Paradoxides* sp. undet.), stating that Nos. 1, 3, 4, 5, 6, and possibly 7, are common to the Primordial slates of St. John, New Brunswick, and to the shales of Manuel's Brook.

In 1887 when reviewing the Cambrian faunas of Cape Breton and Newfoundland Mr. G. F. Matthew[5] described a new species from the Olenellus zone, *Solenopleura bombifrons*, and identified from Manuel's Brook *Paradoxides* sp., *Agnostus gibbus* (?), *Agraulos socialis*, and *Hyolithes* sp. From Trinity Bay he identified in addition to the species mentioned by Mr. Billings *Eocystites* sp., *Agnostus lævigatus*, *A. punctu-*

[1] Geological Survey of Canada; report of progress from its commencement to 1863. Montreal, 1863. pp. 865–867.

[2] Paleozoic Fossils, vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860–1865, p. 363.

[3] On some fossils from the Primordial rocks of Newfoundland. Canadian Naturalist, new ser., vol. 6, 1872, pp. 465–479.

[4] On some Primordial fossils from southeastern Newfoundland. Am. Jour. Sci., 3d ser., vol. 16, 1878, p. 226.

[5] On the Cambrian faunas of Cape Breton and Newfoundland. Roy. Soc. Canada Proc. and Trans., vol. 4, sec. 4, 1887, pp. 147–157.

osus, var., Agnosti of three other species, and ***Microdiscus punctatus.*** From Highland Cove in the same bay, ***Paradoxides davidis, Centropleura loveni, Agnostus punctuosus***, var., ***A. brevifrons, A. lævigatus, A. acadicus***, var. ***declivis.***

In connection with the study of the stratigraphy of the Cambrian rocks of Newfoundland, the writer described[1] a number of species from the lower or Olenellus zone, and the middle or Paradoxides zone. From the former there were ***Obolella atlantica, Coleoloides***, n. gen., ***Coleoloides typicalis, Hyolithes terranovicus, H. similis, Helenia***, n. gen., ***Helenia bella, Microdiscus helena, Olenellus (M.) bröggeri, Avalonia***, n. gen., ***Avalonia manuelensis, Solenopleura harveyi*** and ***S. howleyi.*** From the Paradoxides zone there was described the genus Karlia and the species ***K. minor.***[2]

In 1890 Mr. C. D. Walcott[3] described ***Agraulos strenuus*, var. *nasutus,*** from Manuel's Brook.

NEW BRUNSWICK AND CAPE BRETON.

The first description of the Cambrian fauna as found at St. John, New Brunswick, by Mr. C. Fred. Hartt[4] included the following species: ***Eocystites primævus*** Billings, ***Lingula matthewi, Lingula***, n. s., ***Obolella transversa, Discina acadica, Orthis billingsi, Orthis***, n. sp., ***Conocephalites baileyi, C. matthewi, C. robbi, C. orestes, C. elegans, C. ouangondianus, C. tener, C. aurora, C. thersites, C. gemini-spinosus, C. halli, C. quadratus, C. neglectus, C. formosus, Conocephalites***, n. sp. (?), ***Microdiscus dawsoni, Agnostus acadicus, Agnostus similis, Paradoxides lamellatus.***

It appears that the ***Eocystites primævus*** was submitted to Mr. Billings, to name the genus and species, in manuscript, and was printed in connection with Mr. Hartt's paper. The ***Paradoxides micmac***, figured by Dr. Dawson at the close of Mr. Hartt's paper, was named by the latter in manuscript. The figure is a restoration, and no description accompanies it. In the report of Messrs. Bailey and Matthew[5] it is stated that Mr. E. Billings identified from the St. John group, in the Kennebecasis Valley, fragments of Paradoxides and the pygidium of an Agnostus, three species of Conocephalites, one of Ellipsocephalus, one of Agnostus, what appeared to be a fragment of Salterella, and specimens of Palæophycus of two or three kinds. Among the collections examined by Prof. J. F. Whiteaves for Professor Bailey[6] there is a new

[1] Descriptive notes of new genera and species from the Lower Cambrian or Olenellus zone of North America. U. S. Nat. Mus., Proc., vol. 12, 1889, pp. 33–46.

[2] Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. Nat. Mus. Proc., vol. 11, 1889, pp. 441–446.

[3] The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rept. U. S. Geol. Sur., 1890, p. 654.

[4] Fossils of the Primordial or Acadian group at St. John. Dawson, Acadian Geology, 1868, pp. 641–657.

[5] Preliminary report on the geology of southern New Brunswick. Geol. Surv. Canad., Rep. Prog., 1870-1871, 1872, p. 140.

[6] *Report* on the pre-Silurian (Huronian) and Cambrian or Primordial Silurian Rocks of Southern New Brunswick. Geol. Surv. Can. Rep. of Prog., 1877–'78, 1879, pp. 30, 31 DD.

species of Agnostus and one of Hyolithes noted in association with other species described by Mr. Hartt.

In the year 1883 the first of Mr. G. F. Matthew's[1] memoirs on the fauna of the St. John group made its appearance. In this is given a brief historical review of the work that had already been done upon the fauna by Prof. Hartt, and a statement that from the collections made from time to time during the progress of the Canadian geological survey in New Brunswick Mr. Billings identified fragments of Ellipsocephalus and Salterella and the remains of two species of Hyolithes. Besides these, there are the supposed plant remains of the genera Palæophycus, Eophyton, etc., of the higher divisions of the St. John group.[2] Mr. Matthew made large collections, which were destroyed by the great fire at St. John in the spring of 1877. His published studies were based upon new material collected subsequently to that date.

In the first memoir we find that he recognized three well defined species of Paradoxides and six varieties, as follows: *Paradoxides lamellatus* Hartt; *P. lamellatus* var. *loricatus* Matthew; *P. acadicus* Matthew; *P. eteminicus* Matthew; *P. eteminicus*, vars. *suricoides*, *breviatus*, *quacoensis*, *malicitus*, and *pontificalis*.

A review by Mr. C. D. Walcott[3] of the typical collections upon which Prof. C. F. Hartt based his species, led to a revision of the genera and species, with the following results:

Lingula matthewi	= Acrothele matthewi.
Discina acadica	= Palæacmea (?) acadica.
Theca acadica	= Hyolithes acadica.
Agnostus similis	= Agnostus acadicus.
Microdiscus pulchellus	= Microdiscus punctatus Salter.
Conocephalites matthewi	= Conocoryphe matthewi.
gemini-spinosus	= Conocoryphe matthewi.
baileyi	= Conocoryphe baileyi.
elegans	= Conocoryphe elegans.
robbi	= Ptychoparia robbi.
formosus	= robbi.
ouangondianus	= ouangondiana.
aurora	= ouangondiana var. aurora.
quadrata	= quadrata.
orestes	= orestes.
thersites	= orestes var. thersites.
tener	= tener.
neglectus	= tener.

The genus Harttia and species, *Harttia matthewi*, is proposed for a small patelloid form of gasteropod. Mr. Matthew was requested to give names to the new species, other than the preceding, and he proposed *Lingula ? dawsoni* (p. 15), *Hyolithes danianus* (p. 20.), *Hyolithes micmac*

[1] Illustrations of the fauna of the St. John group. Royal Soc. Canad., Proc. and Trans., vol. 1, sec. 4, 1883, pp. 87-108. Supplementary section, pp. 271-279.

[2] Op. cit., p. 89.

[3] On the Cambrian faunas of North America; preliminary studies. U. S. Geol. Surv. Bull., No. 10, vol. 2, 1884, pp. 283-354, plates.

(p. 21), *Conocoryphe walcotti* (p. 30). The subgenus Salteria was proposed by the author to include the *Conocephalites baileyi*[1] of Hartt.

All of the species were figured and described, with the exception of *Conocoryphe walcotti*. This included figures of the three species of Paradoxides, *P. lamellatus* Hartt, *P. acadicus* Matthew, and *P. dominicus* Matthew.

Some of the results of Mr. G. F. Matthew's studies are given in two papers read before the British Association for the Advancement of Science at the Montreal meeting in 1884. In one he refers to the geological age of the Acadian fauna, and correlates it with the fauna of the St. John group and that of the Solva group of Wales. In the second is given a description of the development of *Ctenocephalus matthewi* and other species of the genus Conocoryphe.[2]

In Mr. Matthew's second memoir on the fauna of the St. John group,[3] presented to the Royal Society of Canada in 1884, additional notes are given of the *Paradoxides acadicus* and *P. lamellatus*. He proposes the name *Paradoxides micmac* for a large species, which he thinks is probably the one figured in Acadian Geology.[4] The original species to which Mr. Hartt intended to apply the name is unknown. The *Conocephalites matthewi* of Hartt is referred to the genus Ctenocephalus of Corda. A detailed description is given of the species, and also of the various stages of its growth, as found in the St. John slates. *Conocoryphe baileyi*, *C. elegans*, and *C. walcotti* are described and figured. In the description of the plate[5] the subgeneric name Hartella is placed after Ctenocephalus and Bailiella after Conocoryphe.

In 1885 *Obolella transversa* Hartt was referred by Mr. C. D. Walcott to the new genus Linnarssonia, together with the closely allied Menevian species, *Obolella sagittalis*.[6]

In a paper read before the Natural History Society of New Brunswick in 1885, Mr. G. F. Matthew stated[7] he had found some Pteropods that appeared to have several distinct septa at the base of the tube. He sent them to Prof. Hyatt, who wrote that the aspect of the siphon is due to the compression of the sharper against the flatter side. The form of the sutures favors this impression. "These fossils with their distinct septa are startlingly similar to certain forms of Nautiloidea, but there is no siphon. They, however, confirm Von Jhernig's and my opinion that the Orthoceratites and Pteropods have had a common, but as yet undiscovered, ancestor in ancient times."

---

[1] Op. cit., pp. 31, 32.

[2] The geological age of the Acadian fauna. The primitive Conocoryphean. British Association Rep., 54th meeting, 1884, pp. 742–743. The geologic age of Acadian fauna. Geol. Mag., new ser., decade 3, vol. 1, 1884, pp. 470–471.

[3] Illustrations of the fauna of the St. John group, continued; on the Conocoryphea, with further remarks on Paradoxides. Royal Soc. Canada, Trans. and Proc., vol. 2, sec. 4, 1885, pp. 99–124.

[4] Op. cit., p. 101. [5] Op. cit., p. 124.

[6] Paleontologic Notes. Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 115.

[7] An outline of recent discoveries in the St. John group. New Brunswick Nat. Hist. Soc. Bull., No. 4, 1885, p. 102.

The third contribution by Mr. Matthew,[1] presented to the Royal Society of Canada in 1885, treats of the Protozoa, Hydrozoa, Brachiopoda, Pteropoda, Gasteropoda, Phyllopoda, Ostracoda, and some of the Trilobita.

Of the Protozoa, *Archæocyathus ? pavonoides*, *Protospongia ? minor*, *P. ? minor* var. *distans*, the new genus Eocoryne and the species *Eocoryne geminum* are described. Of Hydrozoa *Dendrograpsus ? primordialis* Protograpsus, n. g., with the species *Protograpsus alatus*. But one species of the Echinodermata is mentioned, *Eocystites primævus* of Billings. The new forms of Brachiopoda are: *Lingulella ? inflata*, *L. linguloides*, *Acrotreta baileyi*, *A. ? gulielmi*, *Kutorgina latourensis*, *K. ? pterineoides*, *Orthis quacoensis*. Of species previously described *Lingulella dawsoni*, *Linnarssonia transversa* Hartt, *Linnarssonia misera* Billings, *Acrothele matthewi* Hartt, and *Orthis billingsi* Hartt, are described and illustrated.

Among the Pteropods the new subgenus Camerotheca is proposed, and the species *Hyolithes* (*Camerotheca*) *gracilis*, *H.* (*C.*) *dawsonianus*, and *H.* (*C.*) *micmac* are described and illustrated. The genus Diplotheca includes *Diplotheca hyattiana* and the variety *caudata*; also *Hyolithes acadicus* of Hartt, and its varieties, *sericea*, *obtusa*, and *crassa*.

The Gasteropoda include a notice of the genus Stenotheca and the description of the new species, *Stenotheca hicksiana*, *S. concentrica*, *S. radiata*, *S. nasuta*, and *S. triangularis*. The subgenus Parmophorella is proposed to include the original species, *Discina acadica* Hartt. *Stenotheca acadica* and *Harttia matthewi* Walcott are described and illustrated. To the Phyllopoda (?) the new genus Lepiditta, with the species *L. alata* and *L. curta*, and the new genus Lepidilla, with the species *Lepidilla anomala*, are referred. Mr. Matthew says that these forms are very minute, and belong either to lamellibranchs or Phyllopods. The Ostracod Crustaceans include the new genera Hipponicharion and Beyrichona. One species is referred to the former genus, *H. eos*, and two to the latter, *B. papilio* and *B. tinea*. To the genus Primitia he refers one new species, *P. acadica*.

The Trilobita include the new species of Agnostus, *A. regulus*, *A. partitus*, *A. vir*, *A. vir.* var. *concinus*, *A. tessella*, *A. umbo*, *A. obtusilobus*, and *A. acutilobus*. *Agnostus acadicus* Hartt is described and figured and the variety *declivis* proposed. *Microdiscus pulchella* Hartt is placed as a variety of *M. punctatus* Salter, and a new variety, *precursor*, is proposed to be included under *punctatus*. *M. dawsoni* Hartt is also described and figured. Of the larger forms of the Trilobita, *Agraulos* (*?*) *articephalus* is proposed, *Solenopleura acadica* of Whiteaves is figured and described for the first time, and *Paradoxides abenacus* is proposed as a new species. A redescription of *Paradoxides micmac* and the proposal of a variety, *suricus* of *P. acadicus* concludes the references to previously described species.

[1] Illustrations of the fauna of the St. John group, continued. No. III. Descriptions of new genera and species (including a description of a new species of Solenopleura by J. F. Whiteaves). Royal Soc. Canada, Trans. vol. 3, sec. 4, 1886, pp. 29-84. (Proc. for 1885.)

In a synopsis of the fauna in Division 1 of the St. John group, Mr. Matthew[1] notes the occurrence of thirty genera, sixty-five species, and twenty-one varieties of fossils. He states that in a higher horizon in the Kennebecasis Bay area he has found the following association of species:[2]

Anopolinus? sp.	Agnostus (cfr. Nathorsti, Brögg).
Parabolina? sp.	A. (cfr. parvifrons, Linrs.)
Anomocare? 2 sp.	A. umbo.
Ptychoparia, 2 sp.	A. acadicus Hartt, var.
Agraulos socialis Bill., var.	Hyolithes, sp.
Microliscus punctatus Salter, var.?	Linnarssonia transversa Hartt, sp.
Agnostus acutilobus (cfr. gibbus).	

In some preliminary notes on the higher fauna[3] he says that—

The heavy band of black slates which runs through the center of the city of Saint John has yielded the following species, contained in calcareous nodules:

Ctenopyge (cfr.) spectabilis Brögg.	Kutorgina (cfr.) cingulata Bill.
Orthis (cfr.) lenticularis Dal.	Kutorgina?

These indicate a horizon in the upper part of the Lingula flags.

A series of slates are exposed along the north side of the Kennebecasis Basin, whose fossils indicate that they also pertain to the upper part of the Cambrian system:

Conocephalites, a species with broad free cheek and flaring genal spine.	Kutorgina (?), sp.
	Lingulella (cfr.) lepis Salter.
	Lingulella, sp.
Ptychoparia, a small species.	Eophyton linnæanum Torrell, var,
Agnostus (cfr.) pisiformis Ang.	Eophytera, sp.
A. (cfr.) richmondensis Wal.	Arthraria, sp.

In a note to the American Journal of Science Mr. Matthew[4] states that he has found *Olenellus* (?) *kjerulfi* in the Kennebecasis River Basin in band *c* and *d* of his Division 1; and that the same species occurs in the Cambrian beds of Newfoundland. Upon this reported discovery Mr. S. W. Ford[5] endeavored to show that as the species was found at the base of the St. John Paradoxides beds and at the base of the Swedish Paradoxides beds it was a true Paradoxides, and therefore did not influence the question of the stratigraphical position of the Olenellus fauna in North America.

In an abstract of a paper on the Cambrian faunas of Cape Breton and Newfoundland in the Canadian Record of Science, vol. 2, 1886, pp. 255–258, that preceded the main report in the Royal Society of Canada Transactions,[6] Mr. G. F. Matthew points out that the slates of Mira River, Cape Breton, contain several species of trilobites, which show that these measures are in the upper part of the Olenus zone or Lingula flags of Great Britain. The species observed were *Peltura scarabeoides*

[1] Synopsis of the fauna in Division 1 of the St. John group, with preliminary notes on the higher faunas of the same group. New Brunswick Nat. Hist. Soc., Bull. 5. 1886, pp. 25–31.

[2] Op. cit., p. 29. [3] Op. cit., p. 30.

[4] Note on the occurrence of *Olenellus* (?) *kjerulfi* in America. Am. Jour. Sci., 3d ser., vol. 31, 1886, p. 472.

[5] Note on the age of the Swedish Paradoxides beds. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 473–476.

[6] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans., vol. 4, Sec. 4, 1887, pp. 147–157.

Wahl., *Sphærophthalmus alatus*, and *Agnostus pisiformis*. There was also a small Lingulella similar to that which characterizes the upper flags of the St. John group, and an Orthis similar to *Orthis lenticularis* of Dalman.

In discussing the evidence afforded by the smaller-eyed trilobites of Division 1 of the St. John group, Mr. G. F. Matthew[1] speaks of their bearing on the origin of the Cambrian fauna. He also gives a list of fossils known to him at that date from Division 1 of the St. John series. The total is thirty genera, sixty-five species, and twenty-one varieties, the same as in the paper previously mentioned in the synopsis of the fauna of the St. John group.[2] Mention is made by Mr. Matthew of additional species from the St. John group in 1888.[3] In the measures on the St. John River corresponding to those of Band B in Division 1 of the St. John Basin, a calcareous organism that may be referred to Oldhamia has been found. It resembles *O. antiqua*, but branches less freely. In the same sandstone occurs an elegantly ornamented Lingulella (?) of peculiar form. Mr. Matthew compares it with *Lingula ? favosa* of the Eophyton sandstones of Sweden. In Division 2 of the St. John group were found several genera of seaweeds, among which are two graceful species related to Taonurus or Spirophyton; also fragments of bodies of a small crustacean that is probably a Hymenocaris. In a paper published soon after on the "Classification of the Cambrian Rocks of Acadia," Mr. Matthews states[4] that the Lower Potsdam of Billings, or Georgian of Mr. Walcott, is found in the island of Cape Breton, where the fossils are Bathyurus (sub-genus ?), Orthisina, Orthis, and *Hyolithes princeps*. Remarks upon the affinities of the characteristic genera of the Georgian and other portions of the Cambrian fauna occur in this paper.

Mr. Matthew presented Part IV of his illustrations of the fauna of the St. John group to the Royal Society of Canada in 1887.[5] The first species described is the great *Paradoxides regina*, one of the largest trilobites yet discovered in the Cambrian rocks. This is followed by a description of "The smaller trilobites with eyes." An undetermined species is referred to the genus Ellipsocephalus, and *Agraulos? whitfieldianus* is described with its variety *compressa*. The subgenus Strenuella is proposed, with the species *Strenuella ? halliana* as its type. A discussion of the genus Liostracus of Angelin is followed by descriptions of *Liostracus tener* Hartt, *L. ouangondianus* Hartt, and varieties *immarginata*, *aurora*, *gibba*, and *plana*, and a

[1] Illustrations of the fauna of the St. John group, No. IV. Pt. I: Description of a new species of Paradoxides (*Paradoxides regina*). Part 2: The smaller trilobites with eyes (Ptychoparidæ and Ellipsocephalidæ). Royal Soc. Canada Trans., vol. 5, sec. 4, 1888, pp. 115–166.

[2] Illustrations of the fauna of the St. John Group. Canadian Rec. Sci. vol 2, 1887, p. 361.

[3] On the basal series of Cambrian rocks in Acadia. Canadian Record Science, vol. 3, 1888, pp. 28, 29.

[4] Canadian Rec. Sci., vol. 3, 1888, p. 74.

[5] Illustratations of the fauna of the St. John group, No. IV. Pt. 1. Description of a new species of Paradoxides (Paradoxides regina). Pt. 2. The smaller trilobites with eyes (Ptychoparidæ and Ellipsocephalidæ). Royal Soc. Canada, Trans., vol. 5, sec. 4, 1888, pp. 115–166.

notice of the development of the young of this species. Under Ptychoparia, *Liostracus linnarssoni* Brögger is identified from the St. John series. For the narrow form he proposes the variety *alata*, and this is followed by a description of the development of the young. To the genus Solenopleura of Angelin he refers the *Conocephalites robbi* of Hartt, and gives a description of the development of the young as far as known to him. A more extended description of *Solenopleura acadica* of Whiteaves is given, and the variety *elongata* proposed.

In the second paper by Mr. Matthews on the classification of the Cambrian rocks in Acadia[1] the species *Obolus pulcher* is described from the base of Band B of division 1 of the St. John group. In the middle of the band Mr. Matthews recognized an Agraulos and at the base an Ellipsocephalus. This paper also contains a discussion of the Olenellus fauna as found in Nevada. In a paper read later in 1889, entitled "On the Cambrian Organisms in Acadia,"[2] Mr. Matthew states that he has found in this lower series beneath the Paradoxides zone a species that recalls *Fucoides circinnatus* (p. 384), the Obolus which was described later, and undoubted examples of Platysolenites of Pander. In mentioning the fauna and flora of the Paradoxides beds, he says the basket sponges and the rod-like sponges (?) are common to both this and Series B. In all the fine layers of this band species of Protospongidæ may be found, but no examples of the typical Protospongia of the Paradoxides beds have been observed. A new species of Obolus and three species of Lingulella are mentioned as being described in the paper, and the Algæ are represented by several different types, among which are a Buthotrephis and a microscopic form parasitic on the latter organism. There are also some quite small oval forms, resembling Hydrocystium, which may have been algoid. Among the new species of the Paradoxides beds is a little Platyceras. He says that *Paradoxides pontificalis* is found to be a narrow, and *P. micmac* a broad form of *Paradoxides hicksi* of Wales (p. 385). From stage 2, the Olenus beds, he reports abundant remains of a large Protospongia, including *Protospongia fenestrata* of Salter, and *P.* (?) *major* of Hicks, and another large species. From the fossils which appear to have been placed in the upper part of division 2 are some that have been found in Kennebecasis Basin of the Cambrian rocks. These are Leptoplasti, allied to *L. stenotus* of Angelin, *Agnostus pisiformis*, var. and *Agnostus nathorsti*, var. From division or stage 3, the Peltura beds, he mentions two species, Ctenopyge (cf. *C. flagillifer* and *C. spectabilis*), *Orthis lenticularis*, and a Kutorgina. At the bottom of the division *Lingulella lepis* and another large species, *L. ampla*, var.? are found. These beds are correlated with beds of Cape Breton containing species of Peltura, etc. (p. 386).

In a paper by Mr. Matthew, entitled "How is the Cambrian divided?

[1] Canadian Record Science, vol. 3, 1889, pp. 303–315. [2] Ibid., pp. 383–387.

A plea for the classification of Salter and Hicks,"[1] a comparison of the genera of the different horizons of the Cambrian is made.

In the full paper on the Cambrian organisms of Acadia, published in 1890, Mr. Matthew describes the stratigraphic position of the fauna that he considers beneath the Paradoxides beds, and compares it with the lower Cambrian fauna of Sweden and Russia. The new genera and species described are:[2]

Phycoidella, n. g., p. 144.
Phycoidella stichidifera n. sp., p. 144.
Palæochorda setacea n. sp., p. 145.
Hydrocytium (?) silicula n. sp., p. 146.
Microphycus n. g., p. 146.
Microphycus catenatus n. sp., p. 146.
Monadites n. g., p. 147.
Monadites globulosus n. sp., p. 147.
Monadites pyriformis n. sp., p. 147.
Monadites urceiformis n. sp., p. 147.
Radiolarites n. g., p. 148.
Radiolarites ovalis n. sp., p. 148.
Plocoscyphia (?) perantiqua n. sp., p. 148.
Astrocladia (?) elongata n. sp., p. 148.
Astrocladia (?) elegans n. sp., p. 149.
Astrocladia (?) virguloides n. sp., p. 149.
Dichoplectella n. g., p. 149.
Dichoplectella irregularis n. sp., p. 149.
Hyalostelia minima n. sp., p. 150.
Obolus (?) major n. sp., p. 155.
Lingulella martinensis n. sp., p. 155.
Leperditia ventricosa n. sp., p. 159.
Leperditia steadi n. sp., p. 160.

He also describes and illustrates:

Buthotrephis antiqua Brongn., p. 144.
Platysolenites antiquissimus Eichw., p. 150.
Obolus pulcher Matth., p. 151.
Volborthella tenuis Schmidt, p. 156.
Psammichnites gigas Torrell, p. 157.
Arenicolites lyelli Torrell, var. minor, p. 159.

In a note at the close of the descriptions it is stated that he has learned that a suggestion made by him in reference to *Olenellus kjerulfi* has met with acceptance from a number of naturalists and the generic name Holmia is proposed for *Olenellus kjerulfi*.[3] Mention is made of the relations of the genera Olenellus, Olenoides, and Mesonacis.

In his fifth contribution to the illustrations of the fauna of the St. John group Mr. G. F. Matthew describes the following new genera and species:[4] *Platyceras aperta*, n. sp., p. 132, *Agraulos* (?) *holocephalus*, n. sp., p. 138, *Medusichnites*, n. gen., p. 143, with five varieties, *Lingu-*

[1] Am. Geologist, vol. 4, 1889, pp. 139–148.
[2] On Cambrian Organisms in Acadia. Royal Soc. Canada, Trans., vol. 7, 1890, sec. 4, pp. 135–162.
[3] Op. cit., p. 160.
[4] Illustrations of the fauna of the St. John group No. V. Roy. Soc. of Canada, Trans., vol. 8, 1891, pp. 130–166, pls. 11–16.

lella starri, n. sp., p. 146, *Lingulella radula*, n. sp., p. 147, ***Eoichnites***, n. gen., p. 148, *Ctenichnites*, n. gen., p. 151, ***Ctenichnites ingens***, n. sp., p. 151, *Fræna ramosa*, n. sp., p. 159, *Arenicolites brevis*, n. sp., p. 159, *Goniadichnites*, n. gen., p. 160, ***Goniadichnites trichiformis***, n. sp., p. 160, *Monocraterion magnificum*, n. sp., p. 161.

In addition to the preceding Mr. Matthew has remarked upon several genera and species that have been previously described from the Cambrian rocks. They include: *Eocoryne geminum* Matt., p. 130, *Lepidilla anomala*, Matt., p. 130, Orthis and Orthisina, p. 131, *Stenotheca* Salter, p. 132, *Stenotheca concentrica*, Matt., p. 133, var. *radiata* Matt., p. 133, *Stenotheca triangularis* Matt., p. 134. In his remarks upon the genus Stenotheca he concludes that the type species is not a molluscan shell, but should be referred to a Phyllopod crustacean. This includes the typical form, but does not include *Discina acadica*, of Hartt, as the latter is a patelloid gasteropod. *Conocoryphe walcotti* Matt., p. 134, *Conocoryphe baileyi* Hartt, p. 135, *Paradoxides lamellatus* Hartt, p. 135, *Paradoxides micmac*, var., *pontificalis* Matt., p. 136, *Agraulos* (?) *whitfieldianus* Matt., p. 138, *Agraulos socialis* Bill., p. 138, *Medusites princeps* Torrell, p. 140, *Medusites radiata* Nathorst, p. 141, *Medusites costata*, p. 142, *Eoichnites linnæanus* Torrell, p. 148, *Psammichnites* Torrell, p. 157, *Fræna*, Roualt, p. 158, *Monocraterion* Torrell, p. 160, *Monocraterion tentaculatum*, p. 161, *Histioderma hibernicum*, p. 162.

EASTERN MASSACHUSETTS.

The first description of a fossil from the Cambrian rocks of eastern Massachusetts is that of *Paradoxides harlani*, by Dr. Jacob Green,[1] from specimens sent to him by Dr. Richard Harlan, who supposed they came from Trenton Falls, in the State of New York. It was not until 1856[2] that the true horizon from which the specimens came was discovered. In making the announcement of the discovery Prof. Rogers quoted from Barrande on the distribution of the genus Paradoxides, and stated that he considered the specimens from Braintree, 10 miles south of Boston, to be identical with the *Paradoxides harlani* described by Green in 1834. He says the fossils in the Braintree quarry are in the form of casts, some of them of great size and lying in various levels in the strata, and that as far as he could observe they all belong to one species and agree more closely with Barrande's *Paradoxides spinosus* than with any other form known to him. A fine figure of *Paradoxides harlani* was published by Prof. Rogers,[3] in his final report of the geological survey of Pennsylvania, under the name of *P. spinosus*.

Mons. J. Barrande, in referring to the discovery of Paradoxides in the slates of Braintree,[4] institutes a comparison of the specimens from

[1] Descriptions of some new North American trilobites. Am. Jour. Sci., vol. 25, 1834, p. 336.

[2] Proofs of the Protozoic age of some of the altered rocks of eastern Massachusetts, from fossils recently discovered. Am. Acad. Proc., vol. 3, 1856, pp. 315 318.

[3] The Geology of Pennsylvania, Philadelphia, 1858, vol. 2, p. 816.

[4] Trilobiten der Primordial-fauna in Massachusetts. Neues Jahrb. for 1860, pp. 429-431.

there and *Paradoxides spinosus* from Bohemia, and concludes that *P. harlani* is a synonym for *P. spinosus*.

In 1861 Prof. Jackson[1] exhibited a small trilobite from Braintree of the species *Paradoxides harlani*, stating that it seemed identical with forms from Newfoundland described as *Paradoxides bennetti* from St. Mary's Bay. In a foot-note accompanying a paper on the geology of the vicinity of Boston, by Dr. T. S. Hunt,[2] the writer says:

> Mr. Billings informs me that he regards the *Paradoxides bennettii* (Salter) from Newfoundland as identical with the *Paradoxides harlani* (Green) from Braintree.

A number of collectors obtained specimens of *Paradoxides harlani* from the Braintree beds, but it was not until 1861 that a notice of other species appeared. Mr. Albert Ordway[3] stated at a meeting of the Boston Society of Natural History that he had found a fragment of a trilobite which he referred to the genus Ellipsocephalus. He also reported finding a distinct fucoidal impression which shows three branches, each about 4 inches long, but not sufficiently well marked to afford any evidence as to its nature. Mr. Ordway also published a figure of a head of *Paradoxides harlani* when comparing that species with *Paradoxides spinosus*, Boeck., considered by Barrande identical with *P. harlani*.[4]

In his notes on the geology of eastern Massachusetts Mr. W. W. Dodge[5] reviews the then existing information in relation to the fauna of the Paradoxides zone of Braintree—the Braintree slates—mentioning *Paradoxides harlani* and a few obscure traces of fossils found at that locality. A general description of the Cambrian fauna of Wales is given in this connection.

The second described species from the Paradoxides beds of Braintree is *Arionellus quadrangularis* by Prof. R. P. Whitfield.[6] This is probably the species of Ellipsocephalus referred to by Mr. Ordway.

A review of the fauna of the Braintree argillites by Mr. C. D. Walcott[7] included a mention of the species previously described, and a description of a new Pteropod, *Hyolithes shaleri*, and a new species of trilobite, *Ptychoparia rogersi*. The species described by Prof. Whitfield as *Arionellus quadrangularis* was referred to the genus Agraulos.

Under the title of "Preliminary descriptions of North Attleborough fossils" Messrs. N. S. Shaler and A. F. Foerste[8] made the most important contribution to the Cambrian fauna of Massachusetts since the discovery of *Paradoxides harlani*. They identified the fauna as that

---

[1] [On a trilobite from Braintree.] Boston Soc. Nat. Hist., vol. 8, 1861, p. 58.

[2] Boston Soc. Nat. Hist. Proc., vol. 14, 1871, p. 48.

[3] On the occurrence of other fossil forms at Braintree, Mass. Boston Soc. Nat. Hist. Proc., vol. 8, 1861, pp. 5, 6.

[4] Op. cit., p. 3.

[5] Notes on the geology of eastern Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 17, 1875, pp. 405-407.

[6] Notice of some new species of Primordial fossils in the collections of the Museum, and correction of previously described species. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, p. 147.

[7] On the Cambrian Faunas of North America; preliminary studies. U. S. Geol. Surv. Bull. No. 10, vol. 2, 1884, pp. 323-329. Separately paged, pp. 43-49.

[8] Bull. Mus. Comp. Zool., Harv. College, vol. 16, 1888, pp. 27-39.

of the Olenellus zone, as found in the vicinity of Troy, New York. The species described are:

Obolella crassa, var.	H. communis var. emmonsi.
Obolella (?)	H. americanus.
Fordilla troyensis.	H. princeps.
Lamellibranch (?)	H. billingsi.
Scenella reticulata.	Hyolithellus micans.
Stenotheca rugosa, var. paupera.	Salterella curvatus.
S. rugosa var. abrupta.	Aristozoë.
S. curvirostra.	Microdiscus bellimarginatus.
Platyceras primævum.	M. lobatus.
Pleurotomaria (Raphistoma) attleborensis.	Paradoxides walcotti.
	Ptychoparia mucronatus.
Hyolithes quadricostatus.	Ptychoparia attleborensis.

Of these, two genera—Pleurotomaria and Paradoxides—have not heretofore been found in a strongly marked Olenellus zone fauna. A comparison of *Paradoxides walcotti* with specimens of *Olenellus asaphoides* from Troy, New York, of the same size, show them to be generically, if not specifically, identical. This removes Paradoxides from the Olenellus fauna.

Under the view that the Olenellus fauna preceded the Paradoxides fauna Prof. Shaler[1] speaks of *Paradoxides walcotti* as the surviving member of the series, and says the occurrence of the genus indicates close affinities with the Braintree Cambrian horizon. He made careful search for indications of the stratigraphic relations of the North Attleborough and Braintree section but without success. In mentioning the Braintree locality it is stated that a number of distinct remains occur near the Neponset River, and the beds have much the same aspect and are apparently about the same distance from the syenites as those at Braintree.[2]

A notice and description of the fauna found at North Attleborough from the Olenellus horizon, was followed in 1889[3] by the announcement of the discovery of Hyolithes in limestone near East Point, Nahant. Mr. Foerste correlates the limestone and associated shales with those of North Attleborough, and states that the species of Hyolithes appears to be the same as that found at North Attleborough. He proposes the name of *Hyolithes inæquilateralis*. From a study of the type specimens the writer believes it to be identical with *H. communis* var. *emmonsi*.

As now known, the entire Cambrian fauna from eastern Massachusetts includes from the Paradoxides or Middle Cambrian zone four genera and four species, and from the Olenellus or Lower Cambrian zone, twelve genera and nineteen species.

---

[1] On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zool., Harv. College, vol. 16, 1888, p. 21.

[2] Op. cit., p. 23.

[3] Foerste, A. F. The paleontological horizon of the limestone at Nahant, Massachusetts. Boston Soc. Nat. Hist., Proc., vol. 24, 1889, pp. 261–263.

APPALACHIAN PROVINCE.

The Appalachian Province includes the outcrops of Cambrian strata on the line of the Appalachian system of mountains, from the lower St. Lawrence Valley on the north, to Georgia and Alabama on the south.

For the purpose of presenting the historical data the province will be divided as follows:

A. Northern Appalachian district.

B. Southern Appalachian district.

NORTHERN APPALACHIAN DISTRICT.

The northern Appalachian district includes the Hudson River and Lake Champlain area east of the river and lake and an extension northeastward into Canada, as far as the vicinity of Cape Rosier on the St. Lawrence River.

The Hudson River and Lake Champlain area will first be considered. It includes the strata referred to the Cambrian, found on the western slope of the Green Mountains, the foot hills and the more level country stretching westward toward the Hudson River and Lake Champlain.

The earliest reference in the literature to a distinct formation that is now referred to the Cambrian is found in a description of the geology of western Massachusetts and eastern New York. On this account this formation, the "Granular Quartz," will be treated historically as it has been mentioned by authors in Massachusetts, New York, and Vermont, until the year 1861, when its history will be carried forward with that of the "Red Sandrock" and the "Georgia Slates," with which it was then correlated.

GRANULAR QUARTZ.

The first differentiation of a formation referred to the Lower Cambrian in America was made by Prof. Amos Eaton in 1818.[1] Prior to that time Mr. William Maclure, the pioneer of systematic geology in America, published a map with descriptions of the rocks of the Eastern United States, in which all the strata now referred to the Cambrian system in the Appalachian range were included in the Transition series. On his first map[2] the Transition rocks are represented as extending from Hudson, in the valley of the Hudson, south to the vicinity of Poughkeepsie, and thence southwest throughout New York, New Jersey, Pennsylvania, Virginia, eastern Tennessee, northern Georgia, and into Mississippi. On the map accompanying a later work[3] the Transi-

[1] An index to the geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 52.

[2] Observations on the geology of the United States explanatory of a geological map. Am. Phil. Soc. Trans., vol. 6, 1809, pp. 411-428, map.

[3] Observations of the geology of the United States; with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils. With a map and two plates. Am. Phil. Soc. Trans., new ser., vol. 1, 1817, pp. 1-91.

tion rocks are extended north into the valley of Lake Champlain as far as the Canadian border. On the south they terminate in Georgia a short distance south of the Tennessee line.[1]

In his first publication on the rocks between the Catskill Mountains west of the Hudson River and the Atlantic Ocean, Prof. Amos Eaton[2] separated the "Granular Limestone and Quartz" as No. 2 of the section, and an argillaceous and siliceous slate as No. 9, giving the localities at which they occur. Two years later this classification was reviewed[3] and the "Granular Quartz" dropped out of the nomenclature, only to reappear again with a very accurate description of the formation as it occurs in Vermont.[4] It is interesting to note in this publication, that the "Granular Limerock" is mentioned as accompanying the "Transition Granular Quartz" from Whitehall on Lake Champlain, to Barnegat on the Hudson. Up to this time Prof. Eaton appears to have regarded the terms "Granular Quartz" and the "Granular Limerock" as interchangeable. In the classification of 1824,[5] however, the "Granular Quartz" is separated from the "Granular Limerock" and fully described. The "Transition Argillite" and the "Primitive Argillite" are also defined, and some of the localities given are now known as localities of Lower Cambrian slates. The geologic profile accompanying the memoir of 1824 exhibits the differentiation made by Prof. Eaton in the classification of the rocks between the primitive granite and the secondary.

In the geologic nomenclature of to-day the "Granular Quartz" is included in the Lower Cambrian, and the "Granular Limerock" equals the Trenton-Chazy-Calciferous limestone. The "Primitive Argillites" of Williamstown Mountain equal the Upper Hudson or Lorraine shales. The "Transition Argillite" is nearly all Cambrian, with the exception of a small portion near the Hudson River. The Calciferous sandrock is of the same age as the "Transition Argillite." The Graywacke of Peterborough Mountain, and the Metalliferous limerock is of Silurian (Ordovician) age. The "Transition Argillite" is mostly of Lower Cambrian age, and much of the so-called Calciferous sandrock and Graywacke of the section, represented as resting on the upturned edges of the "Argillite," are portions of the same series to which the "Argillite" belongs. Near the Hudson River a profound fault

[1] In a review of Maclure's memoir by C. S. Rafinesque it is suggested by him that "We must especially collect and describe all the organic remains of our soil, if we ever want to speculate with the smallest degree of probability on the formation, respective age, and history of our strata." (Observations on the geology of the United States of America, by William Maclure, a notice. Am. Monthly Magazine, vol. 3, 1818, pp. 41-44.)

[2] An Index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818.

[3] Eaton, Amos. An Index to the Geology of the Northern States, 2d ed., 1820, pp. 154-212.

[4] Eaton, Amos. A geological and agricultural survey of Rensselaer County, New York, with a geological profile from Onondaga to Massachusetts, p. 15, plate. Albany 1822. Memoirs of the board of agriculture of the State of New York, 1823, vol. 2, p. 9.

[5] A geological and agricultural survey of the district adjoining the Erie Canal, 1824, pp. 30, 56–58, plate. Albany.

with a great horizontal thrust has forced the Lower Cambrian over and on to the Silurian (Ordovician) rocks. The misunderstanding of the true relations of these rocks and a dependence upon their lithological characters led Prof. Eaton into an error that has come down to the present day in memoirs relating to the "Taconic System."

Prof. Eaton reviewed his work from time to time until 1832, when his final scheme of classification appeared. It is reprinted in the following tabulation, with the equivalents of his formations as known in the nomenclature of to-day.[1]

	Eaton's Nomenclature (1832).		1891.
III.—Lower Secondary.	3. Corniferous limerock		Upper Helderberg.
	3. Geodiferous limerock		Niagara.
	2. Millstone grit and rubble	Second Graywacke	Oneida, Clinton, Medina.
	1. Second Graywacke slate.	Second Graywacke	Utica, Hudson.
II.—Transition.	3. Metalliferous limerock		Trenton.
	3. Calciferous sandrock		Calciferous.
	3. Sparry limerock		Trenton, Chazy.
	2. Millstone grit and gray rubble	First Graywacke.	Lower and Middle Cambrian and Silurian.
	2. Graywacke slate	First Graywacke.	Hudson.
	1. Argillite: Roof slate, Wacko slate, Clay slate		Considerable Hudson, but includes a great mass of Lower Cambrian in Rensselaer County, N. Y.
I.—Primitive.	3. Granular limerock		Trenton-Chazy limestone, Calciferous. Cambrian limestone.
	2. Granular quartz		Lower Cambrian.
	1. Granite, Mica slate, Hornblende and Talcose rock		Algonkian, pre-Cambrian, and Archean.

The stratigraphic position of the "Granular Quartz" (2 of the Primitive) is correctly represented, and it is now known to contain *Olenellus* sp.? A large portion of the strata referred to the "Argillite" (1, of the Transition) is also known to carry *Olenellus asaphoides* and to belong to the Lower Cambrian terrane. In the text the "Graywacke slate" (2, of the Transition) is described as resting unconformably upon the upturned edges of the "Argillite" (1), and it is so represented in the section. This is essentially the same as the section of 1820 and as in the more detailed section of 1824.

Rev. Chester Dewey studied the geology of the vicinity of Williamstown, Massachusetts, and in 1819[2] published a short sketch of the mineralogy and geology of this region. He followed this in 1820 by a geologic section from the Taconic range in Williamstown to the city of

[1] Geological Text-book for aiding the study of North American Geology; being a systematic arrangement of facts collected by the author and his pupils under the patronage of the Hon. Stephen Van Rensselaer. Second edition, 5 plates. Albany, 1832.

[2] Sketch of the Mineralogy and Geology of the vicinity of Williams' College, Williamstown, Massachusetts. (With a map.) Am. Jour. Sci., vol. 1, 1819, pp. 337–346.

Troy, on the Hudson.[1] In this section the relations of the quartz formation to the mica slates of the Archean are shown, and in a general way the Lower Cambrian slate is described. This is referred to the Transition argillite. In 1824[2] he described the formation more in detail. On the map accompanying this paper the distribution of the various rock masses is more accurately given than in any maps published prior to those of Prof. James D. Dana, when studying the strata referred to the Taconic system. It exhibits an acquaintance with the surface distribution of the rock masses and a clear comprehension of the classification and correlation of rocks on the principle of lithologic characters. The distribution of the Granular Quartz and its relation to the subjacent primitive rocks, or the mica slate of the map, is particularly well worked out.

Dr. E. Emmons, a pupil of Prof. Eaton, adopted the order of succession of the strata as proposed by Eaton, and separated the "Granular Quartz" (2), "Granular Limerock" (3), and "Argillite" (1) to form a distinct series of rocks between the "Granite" (1) and the "Graywacke" (2) of the Transition. To this series of rocks he gave the name "Taconic," as Nos. 3 and 1 are largely developed in the Taconic range of mountains. His central idea was that the rocks were non-fossiliferous and beneath the zone of animal life, and were separated by their mineralogical characters from the subjacent and superjacent rocks.[3]

In accordance with the belief that the "Granular Quartz" belonged to a system of rocks which were beneath the zone of animal life, Dr. Emmons considered it the oldest of the sedimentary rocks, and far beneath the Potsdam sandstone surrounding the Adirondack mountains. He thus differentiated the Potsdam sandstone and the "Granular Quartz" as two distinct formations. The work of Messrs. Dewey and Emmons added little to the knowledge of the true position of the "Granular Quartz" in the geologic series, as they did not discover fossils in it or the associated formations.

Prof. H. D. Rogers, in summing up the results of his study of the marbles and sandstones of the western portion of Berkshire County, Massachusetts, states that he considered the Berkshire limestone and marble to be the equivalent of the (Trenton) limestone series of the New York section; and that the semi-vitrified quartz was equivalent to the sandstone at the base of the same series (the Potsdam sandstone).[4] In the same year, 1841, a discussion of these formations was published in

[1] Geological section from Taconick range, in Williamstown, to the city of Troy, on the Hudson. Am. Jour. Sci., vol. 2, 1820, pp. 246–248.

[2] A sketch of the geology and mineralogy of the western part of Massachusetts, and a small part of the adjoining States. Am. Jour. Sci., vol. 8, 1824, pp. 1–60.

[3] Geology of New York, Part 2, comprising the survey of the second geological (Northern) district, 1842, pages 135–164.

[4] Some observations on the geological structure of Berkshire, Massachusetts, and neighboring parts of New York. Am. Phil. Soc. Proc., vol. 2, 1841, pp. 3, 4. On the physical structure of the Appalachian Chain, as exemplifying the laws which have regulated the elevation of great mountain chains generally. Trans. Am. Assoc. Geol. Nat., 1842, p. 482.

the Geology of Massachusetts,[1] in which the quartzite is described with many details. In the table on page 303, the "Granular Quartz" is placed at the base of the Paleozoic, or Sedimentary series, that is, at the base of the stratified rocks.

Dr. W. W. Mather,[2] in his survey of this region, concluded with Prof. Rogers that the "Granular Quartz" and other rocks referred to the Taconic by Emmons were the same as those of the Champlain division of the New York section, modified by metamorphic agency and the intrusion of Plutonic rocks. This correlates the "Granular Quartz" with the Potsdam sandstone. The "Granular Quartz" and the Potsdam sandstone were referred to the Primal series by Prof. H. D. Rogers[3] along with all the quartzites that were found at the supposed base of the Paleozoic series in the Appalachian region and north through New York and Vermont into Canada, and westward into the Mississippi Valley. This reference to the Primal series is more fully described in the final report of the Geological Survey of Pennsylvania.[4]

Prof. Ebenezer Emmons described the "Granular Quartz" with considerable detail as the basal member of his Taconic system.[5] In the reports of 1844 and 1847 its occurrence in western Massachusetts and western Vermont is noticed, and it is stated that in all probability it occurs as far north as the Canadian border. Its extension into Vermont had been previously noted by Messrs. Eaton and Dewey, and we find in the first annual report of the Vermont survey the statement by Prof. C. B. Adams[6] that a quartz rock constitutes the western base of the Green Mountains from the north part of Addison County to Massachusetts; and it is further said[7] that the quartz rock accompanies the Stockbridge limestone, disappearing with it in the north part of Addison County, and that near Lake Dunmore a bowlder was found in the vicinity of the quartzite beds containing two remarkable species of Polyparia(?). Two years later, in speaking of an excursion into Bennington County Prof. Adams says that the Quartz rock may equal the Potsdam sandstone, but there has evidently been too great a disturbance in this region to admit of certain conclusions.[8]

A full description of this formation is presented under the heading of

---

[1] Final report on the geology of Massachusets, vol. 2, 1841, pp. 560–593.

[2] Mather, William. Natural History of New York. Pt. 1, Geology of New York; geology of the first (southeastern) district. Albany, 1843, p. 438.

[3] On American Geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, pp. 151–154.

[4] The geology of Pennsylvania. Philadelphia, 1858, vol. 2, p. 751.

[5] Geology of New York, pt. 2, comprising the survey of the second geological (northern) district. 1842, pp. 135–164. The Taconic System; based on observations in New York, Massachusetts, Vermont, and Rhode Island, pp. i–vii, 67, 6 plates, Albany, 1844. Agriculture of New York, vol. 1, pp. 45–112, plates 21, map. Albany (1846), 1847. American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. 8vo. Albany, 1856, vol. 1, pt. 2, pp. 122.

[6] First Annual Report on the Geology of Vermont. Burlington, 1845, p. 57.

[7] Op. cit., p. 61.

[8] Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, p 13.

"Quartz Rock" in the final report of the Geological Survey of Vermont by Prof. C. H. Hitchcock.[1] Detailed descriptions are given of its character as found in Vermont, where it is said to have a thickness of at least 1,000 feet.[2] On this same page we read that "much of the quartz rock in the valley between Bristol and Starksboro can not be distinguished from members of the red sandrock series." Several species of fossils are mentioned as occurring in it; they are: A species of Lingula, a mollusk, resembling the Modiolopsis, a straight chambered shell (?), a few crinoidal columns, the *Scolithus linearis* (Hall), a few fucoids, and some indeterminable forms which are evidently organic.[3] The exact geological horizon of the quartz rock is not determined.

At this point the review of the literature referring to the "Granular Quartz" will be postponed until it is taken up in connection with the "Red Sandrock" and "Georgia Slates" of Vermont. In 1861 the three formations were practically united in one geologic terrane by the discoveries of Messrs. Billings and Barrande and the correlations of the Geological Survey of Vermont. A review of the references made to the Red Sandrock and the Georgia Slates will next be given, and then the three formations will be considered together as they are described in New York and Vermont.

RED SANDROCK.

When describing the formation terminating the Champlain group of the New York section Dr. E. Emmons correlated the brown or red-brown sandstone of Vermont, on the eastern border of Lake Champlain, as found at Addison, Charlotte, Burlington, and Colchester, with the gray sandstones that terminate the Lorraine shales of Jefferson County, New York.[4] He thus assigned the "Red Sandrock" of the future to the summit of the Lower Silurian.

In presenting the results of his study of a section crossing Vermont from the Green Mountains to Lake Champlain, Prof. C. T. Jackson[5] mentions the occurrence at Burlington Falls of a red sandstone containing numerous beds of buff-colored and blue compact limestone destitute of fossils. He referred it to the Potsdam sandstone of Dr. Emmons. "At Willard's quarry the red sandstone rock alternates with a bright red slate, covered with ripple marks made by the waters, from which the sediment was originally deposited." He further states that a mile from Burlington, on the Winooski River, large beds of compact blue and excellent white limestone are found.

Prof. C. B. Adams describes in the first report of the Geological

[1] Hypozoic and Paleozoic rocks. Report on the Geology of Vermont, descriptive, theoretical, economical, and scenographical, vol. 1, 1861, pp. 342–357.

[2] Op. cit., p. 355.

[3] Op. cit., p. 356.

[4] Geology of New York, pt. 2, comprising the survey of the second geological (northern) district. 1842, pp. 123, 124.

[5] *Final Report* on the Geology and Mineralogy of the State of New Hampshire, with contributions towards the improvement of agriculture and metallurgy. Concord, 1844, p. 161.

Survey of Vermont the occurrence of roofing slates in southern Vermont[1] which he refers to the Taconic slate of Dr. Emmons, without a further attempt to assign them to a geologic horizon.

In the following year a section is given of Snake Mountain by Prof. Adams[2] in which the Red sandrock is shown resting conformably upon the Hudson River shale. In 1847 he referred to his studies of the Red sandrock[3] and noticed the discovery of fragments of trilobites which Prof. James Hall identified as Conocephalus.[4] He next assigned his Red Sandrock to the Upper Silurian, correlating it with the Medina sandstone.[5] Dr. E. Emmons criticised this view of Adams, and stated that he was in error. He regarded the formation as of Calciferous or of Potsdam age as proved by the fossils, stating that the rocks rest on the Taconic slate.[6] Prof. Adams reasserted his view in 1848,[7] stating that no line of fracture occurred above the Trenton limestone, and that the Snake Mountain section showed that it contained Utica and Hudson River rocks. Later, Dr. Zadock Thompson adopted the view that the Red sandrock was in its natural position on the summit of Snake Mountain.[8] The view that the Red sandrock series was the equivalent or the Medina of the New York section was sustained by Prof. W. B. Rogers[9] and the Medina or Clinton age of the "Red sandrock" was supported by the Geological Survey of Vermont.[10]

Mr. E. Billings, on learning of the discovery of fossils in the "Red sandrock" near Swanton, Vermont, by Dr. G. M. Hall and Rev. J. D. Perry, visited the locality and found a small Theca and a Conocephalites. Upon this paleontological evidence he referred the strata to about the horizon of the Potsdam sandstone, to which position it has since been assigned by most authors who have had occasion to mention it.[11] Mr. Billings also corrected the statement of Prof. Hall, that the trilobites of the Georgia slate were from the Hudson terrane, and referred them to the Primordial or Lower Potsdam. This transferred the Georgia series and the associated "Red sandrock" to the Cambrian.[12]

I have thus far referred only to the "Red sandrock," as it was mentioned more definitely, and assigned to a geological position prior to the argillaceous and arenaceous shales and slates that overlie it. As the "Red sandrock" and these shales or slates will be spoken of together

[1] First Annual Report on the Geology of Vermont. Burlington, 1845, p. 35.

[2] Second Annual Report on the Geology of the State of Vermont. Burlington, 1846, p. 163.

[3] Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, pp. 13–15.

[4] Letter on certain fossils in the Red sandrock of Highgate. Third Annual Report on the Geology of the State of Vermont. Burlington, 1847, p. 31.

[5] On the Taconic System. Am. Jour. Agric. and Sci., vol. 6, 1847, p. 260.

[6] (On the Taconic System.) Am. Jour. Agric. and Sci., vol. 6, 1847, p. 260.

[7] On the Taconic Rocks. Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 108–110.

[8] Geology of Vermont. Nat. Hist. of Vermont, Burlington, 1853, Appendix, p. 45.

[9] (Notes on the geological structure of western Vermont.) Report on the Geology of Vermont, vol. 1, 1861, pp. 326, 327.

[10] Hitchcock, C. H. Report on the geology of Vermont. Notes on the sections, vol. 2, 1861, p. 650.

[11] On the age of the red sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

[12] On Prof. J. Hall's claim to priority in the determination of the age of the red sandrock series of Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 370–376.

hereafter, I will now go back and give a short résumé of the history of the latter as mentioned by various authors.

GEORGIA SLATES.

The first notice we find of the slates and shales now referred to the Georgia terrane of Vermont is by Prof. Amos Eaton, in 1818. The argillaceous and siliceous slates and, in isolated masses, a graywacke slate (Nos. 9 and 10 of his figured section) are shown to the east and west of the Hudson River, the slates on the east alone belonging to the Cambrian.[1] These slates were referred to the transition class.[2] In the next edition of his index[3] these beds are referred to the Argillite (7) and the Graywacke (9), these terms being then applied to them as seen in Rensselaer County, New York, and in all of Eaton's subsequent publications. It is the Argillite (1) and the First Graywacke or the Graywacke slate of the First Graywacke of the nomenclature of 1832[4] and his paper of 1839.[5] On Rev. Chester Dewey's Geological Map of 1824[6] the same area in Rensselaer County is included under the term "Grey Wacke" and in part "Transition Argillite."

In defining the limits of the Taconic System in 1844,[7] the northward extension of Prof. Eaton's Argillite and Graywacke of Rensselaer County into Washington County was called the Taconic slates, and it was in this series, a mile north of Bald Mountain, that the first fossils of the Olenellus or Lower Cambrian zone were found by Dr. Asa Fitch. These slates, with their interbedded arenaceous layers, formed the Upper Taconic of Emmons, which he stated could be traced northward to the Canadian border. In the map accompanying Dr. Emmons's memoir on the Taconic System, published in 1844, all of the strata east of the Hudson are colored Taconic slates, or included in the Taconic system. The same strata in the map of 1842, published by the Geological Survey of New York, are included under the Hudson River group.

Dr. Asa Fitch, a practicing physician in Washington County, New York, studied the local geology, and, under the headings of "Taconic

[1] The Greywacke or Grit area of the eastern part of Rensselaer County is now known to be above the metalliferous limestone of Eaton or the Trenton limestone series of the New York State Survey. The recent work of Mr. T. Nelson Dale, of the U. S. Geological Survey, establishes this and proves that I was incorrect in referring this area to the Cambrian on the map accompanying the paper on the Taconic System of Emmons and the use of the name Taconic in geologic nomenclature. (Am. Jour. Sci., 3d ser., vol. 35, 1888, pl. 3.) It is probable that the eastern portion of the Cambrian area, as there mapped, to the north of the Berlin Grit area, in western Bennington and Rutland counties, Vermont, may also prove to be of Lower Silurian (Ordovician) age. (C. D. W., June, 1891.)

[2] An index to the geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 27–30.

[3] An index to the geology of the Northern States. 2d ed., 12mo, Troy, N. Y., 1820, p. 163.

[4] Geological Text Book. 2d ed., 1832.

[5] Cherty lime-rock or Corniferous lime-rock proposed as the line of reference for State geologists of New York and Pennsylvania. Am. Jour. Sci., vol. 36, 1839, pp. 69, 70.

[6] A sketch of the geology and mineralogy of the western part of Massachusetts and a small part of the adjoining States. Am. Jour. Sci., vol. 8, 1824, pp. 1–60.

[7] Emmons, E. The Taconic System; based on observations in New York, Massachusetts, Vermont and Rhode Island. Albany, 1844, pp. i–vii, 67, 6 plates.

slate" and "Taconic sandstone,"[1] gives a description of the slates and interbedded sandstone with considerable detail. He thinks that they may belong to an older system than the New York rocks, but no evidence is given to support this view. On page 865, Dr. Fitch states that in the summer of 1844 he found at Reynold's Inn the first fossils known from the Taconic slate, and sent them to Dr. Emmons, who named and published illustrations of two species. Dr. Fitch also describes an annelid trail, *Helminthoidichnites tenuis*, from the "Taconic slate" of Granville.[2]

Dr. C. B. Adams, of the Geological Survey of Vermont, called the northward extension of the Upper Taconic slate (of Emmons) of Washington and Rensselaer Counties, the roofing slates of the Taconic system, and included them in his Hudson River group.[3]

The fossils described from a locality of this horizon, near Troy, New York, in the paleontology of New York,[4] were included by Prof. James Hall with those of the Hudson River group and were considered to be of that age. This same view was taken by him of the northward extension of this series in Vermont, when he described the trilobites from the shales of Georgia in 1859. At the close of this article he says:[5]

> In addition to the evidence heretofore possessed regarding the position of the shales containing the trilobites, I have the testimony of Sir W. E. Logan that the shales of this locality are in the upper part of the Hudson River group, or forming a part of the series of strata which he is inclined to rank as a distinct group above the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able stratigraphical geologist of the American continent.

Prof. C. H. Hitchcock,[6] in speaking of the trilobite rock of Vermont, from which Prof. Hall's specimens were obtained, stated that he considered them as overlying the equivalent of the Oneida, which was superjacent to the Hudson River Rocks.

The attention of M. Joachim Barrande having been called to the fossils found in the Georgia slate, he studied them with great care, and published an extended review of the literature referring to them, and discussed the paleontologic proof of the age of the rocks.[7] He decided that the fauna was equivalent to his Primordial fauna of central Bohemia, and that it could not be referred to the Second fauna, as had been done by the American observers. Under the impression that Dr. Em-

[1] A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850, pp. 830–857.

[2] Op. cit., p. 868.

[3] First Annual Report on the Geology of the State of Vermont, Burlington, 1845, p. 61. On the Taconic Rocks, Am. Jour. Sci., 2d series, vol. 5, 1848, pp. 108–110.

[4] Palæontology of New York, vol. 1, containing descriptions of the organic remains of the lower division of the New York system, 1847, pp. 252, 256, 257.

[5] Remarks upon the trilobites of the shales of the Hudson River group. Paleontology of New York, vol. 3, supplement to vol. 1, 1859, p. 529.

[6] On the geology of Vermont, chiefly in connection with the Taconic System. Boston Soc. Nat. Hist. Proc., vol. 7, 1861, pp. 426, 427.

[7] Documents anciens et nouveaux sur la faune primordiale et le système taconique en Amérique. Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 203–321.

mons's stratigraphic work was correct, M. Barrande credited him with having correctly located the Primordial fauna in America.

In 1861 Prof. Hall changed the reference of the Georgia trilobites from the Hudson River group to the Quebec group.[1] In a letter written to M. J. Barrande, dated April, 1862, the explanation of this is given. He states that his own conviction was that the Red sandrock and the Granular Quartz of Vermont were of the age of the Potsdam sandstone and that the schists and shales which held the trilobites belong between the Potsdam sandstone and the Trenton limestone. He thus changed his views in relation to the age of the rocks containing Olenellus and other trilobites, and referred them to the lower portion of what is now designated as the Silurian (Ordovician). He says:

> You will understand, then, that if my views touching the relations of these rocks are exact the valley of the Hudson River from the high lands on the south of Lake Champlain, save a small number of inconsiderable exceptions, is occupied by rocks of the Primordial zone, that is, by rocks placed between the Potsdam sandstone and the Trenton group. Thus the Hudson River group in its typical localities belongs to the Primordial period.[2]

In explaining how he came to adopt the view that the trilobites from the Georgia slates of Vermont and those described by Dr. Emmons from the black slates of Washington County belonged to the Hudson River group, together with the strata in which they were contained, he says:

> I wish to claim nothing for myself or for my former views, for we owe the final solution of this question to the Canadian survey. Yet there remain some divergent views in regard to the relation between the shales and the Potsdam sandstone.

He further states that this arose from his seeing the Potsdam sandstone run beneath the slate at Whitehall, New York, and a number of other places; that at no point where the Potsdam sandstone is seen is there any shale or other formation beneath it, excepting the crystalline rocks of the Adirondacks. Speaking of the "Granular Quartz," he says that it presents the same relation as the Potsdam sandstone to the schistose rocks; that he has always referred it without hesitation to the Potsdam sandstone. He held the view that the schistose rocks, with their impure sandstones, brecciated limestones, and calciferous sandrock, are to be placed between the Potsdam sandstone and the Trenton limestone group; that the relation of this group of schists or slates to the Potsdam sandstone seems to be that of an upper formation. In none of the outcrops that he saw in the disturbed region east of the Hudson was there one that could explain the phenomena presented, on the supposition that the sandstone is the upper rock. He then quotes the nomenclature of Eaton to show that it was almost the same as that finally adopted by the Geological Survey of New York, that is, the order of superposition of the formations, the "Granular Quartz" being placed at the base. It is also stated that the graptolites found in the beds

[1] Correction for the thirteenth annual report. 14th Ann. Rep., State Cab. Nat. Hist., 1861, p. 110.

[2] *Letter* on the Primordial of America. Soc. géol. France, Bull., 2e sér., vol. 19, 1862, p. 732.

formerly referred to the Hudson River are considered to belong to the Primordial fauna.[1]

The geologists of the Vermont survey in their final report included the shales and associated slates and arenaceous beds under the title of Georgia group. In proposing the name Georgia group to designate these rocks, Prof. C. H. Hitchcock said:[2]

> We use the term *Georgia group* to designate this terrain, from the town of Georgia in Franklin County, where it is developed in its full proportions and where the most interesting fossils have been found. It is a name also which does not involve any theory, and may be used by both parties in the controversy respecting its age. * * * The Georgia slate includes what Prof. Emmons has ranked as the black slate, Taconic slate, and roofing slate; and yet not altogether, for we have regarded all the black slate beneath the red sandrock as belonging to the Hudson River group. The characteristic trilobites of the Georgia slate are represented by Emmons in his Taconic System, 1844, as found in the black slate.

The following fossils are cited as characterizing the Georgia slate in Vermont: *Barrandia thompsoni* Hall, *B. vermontana* Hall, *Bathynotus holopyga* Hall, *Graptolithus milesi* Hall, the trail of an annelid, and unknown species of fucoides.[3]

The stratigraphic position of the Georgia series was considered to be above the sandstone which represented the Oneida conglomerate, and the thickness of the slate was thought to be at least 3,000 feet.[4] A discussion of the stratigraphic position of the faunas found in the Georgia slates by Prof. James Hall, Sir William E. Logan, and M. J. Barrande, accompanies the chapter. A fair presentation of the argument for and against the Silurian age of the terrane is given. In a note upon the trilobites of the shales of the Hudson River group, in the same volume, Prof. Hall redescribes the fossils mentioned in his paper of 1859. In the second volume of the Geology of Vermont, on page 799, the "sparry limestones" occurring as thin bands in the roofing slate series in Fairhaven, Vermont, are correlated with the red sandrock or Winooski marble of the northern portion of the State.

In describing the rocks of Waterville, Maine, Prof. C. H. Hitchcock[5] states that the slates are similar in mineralogical structure to the Georgia slates of Vermont, which are equivalent to the Potsdam sandstone.

With the determination (*a*) by Mr. E. Billings that the "Red sandrock" was of primordial age;[6] (*b*) by Mons. Barrande that the fossils from the Georgia slate belonged to the Primordial fauna; (*c*) that the "Granular Quartz" was the basal member of the Paleozoic, and had been correlated with the Potsdam sandstone, which, from its included

---

[1] Op. cit., p. 732.

[2] Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 358.

[3] Op. cit., p. 367. [4] Op. cit., p. 366.

[5] General report on the geology of Maine. Preliminary Rep. on the Nat. Hist. and Geology of Maine. Augusta, 1861, p. 233.

[6] On the age of the red sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

fossils in the Mississippi Valley, was also referred to the Primordial, the review of the history of these three Cambrian formations as they appear in New York and Vermont is carried forward as that of one terrane.

In speaking of the determination of the age of the slates in Georgia, Vermont, Mr. E. Billings states that Mons. Barrande first determined their age.[1] He further says:

> At the time I wrote the note on the Highgate trilobites it was not known that these slates were conformably interstratified with the Red sandrock. This discovery was made afterwards by the Rev. J. B. Perry and Dr. G. M. Hall, of Swanton.

He also mentions the discovery on the Straits of Belle Isle, by Mr. J. Richardson, of the Canadian Geological Survey, of *Scolithus linearis*, *Paradoxides thompsoni*, and *P. vermontana*, and a number of other species of which a list would be given further on. He adds:

> The sandstones and limestones of the north shore of the straits [of Belle Isle] appear to be of the age of the Potsdam of Pennsylvania and Tennessee. The form of the Scolithus is identical with that which occurs in these two States, and some portions of the rock is a coarse red sandstone, exactly like the specimens sent to me about a year ago from Tennessee by Prof. Safford.

Mention is made of the discovery by Rev. J. B. Perry and Dr. G. M. Hall of a group of fossils interstratified with the Red sandrock east of Swanton, Vermont. Of the species found, four occur in the limestone which overlies the sandstone with *Scolithus linearis* on the north shore of the Straits of Belle Isle.

> Taking all these facts together scarcely anything more is necessary to show that the Red sandrock of Vermont is of the age assigned to it by me from an examination of Conocephalites at Highgate in July last. * * * Barrande's opinion, founded altogether upon the aspect of these trilobites is thus completely verified.[2]

At the close of the paper is a list of the fossils found in Vermont and on the Straits of Belle Isle, all of which are referred to the Potsdam group.[3] In speaking of the claim of Mr. Billings, that he had identified the Primordial fauna in the Red sandrock and determined its geological age, Prof. James Hall[4] states that he had published sections and made statements in relation to the age of these rocks to show that he considered them to be of the age of the Potsdam sandstone of the New York section. In reply Mr. Billings[5] said that the sections spoken of by Prof. Hall do not cross at any point the Red sandrock or Georgia slates, where they are recognized by Prof. Hall as belonging to the Potsdam. On the contrary, they are marked on the section as belonging to the Trenton-Hudson series.

---

[1] Further observations on the age of the red sandrock formation (Potsdam group) of Canada and Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 100–105. (See note and corrections, same vol., pp. 421–422.)

[2] Op. cit., p. 102. [3] Op. cit., p. 104.

[4] On the Potsdam sandstone and Hudson River rocks in Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 106–108.

[5] On Prof. J. Hall's claim to priority in the determination of the age of the Red sandrock series of Vermont. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 370–376.

When tracing the formations that occur north of the Vermont and Canada boundary to the southward, Sir William E. Logan studied a section in the vicinity of Swanton, Vermont, in which the Georgia slates and the Olenellus fauna occur above the Red sandrock.[1] The latter are red and white dolomites in sandy layers. The measurement of this section gave a thickness of 710 feet, including 190 feet of shale, carrying the fossils which Mr. Billings described. He traced the rocks of the Swanton section north to the vicinity of Saxe's Mill, near the United States and Canadian border, where a measured section of the dolomitic sandstone gave a thickness of 1,410 feet.[2] These sections cross the Red sandrock formation of the older authors. The name Red sandrock is a misnomer, as there is in reality comparatively little sand or arenaceous material, other than arenaceous limestone of a highly dolomitic character, in the entire section.

Prof. Jules Marcou took a very active interest in the discussion of the stratigraphic position of the fauna found in the slates of Georgia, Vermont, and published numerous papers upon the subject from 1860 to 1888. In a paper published in 1861[3] he records some of his own observations, saying that in Vermont the Potsdam sandstone has exactly the same aspect and composition as at Potsdam, in the State of New York. Near Saxe's Mills, a mile east of Highgate Springs, it contains two species of Conocephalites, *C. adamsi* and *C. vulcanus*. He states that the formation is broken up into narrow bands that are numerous and well developed west of Mr. Parker's farm at Georgia, and also on the road between St. Albans and Swanton, Vermont; and that although at first they appear to be interstratified with the Georgia slates, they are not so, but may be compared with the steps of a ladder placed over, or even a little wedged into the Georgia slates and Lingula flags. He says:

> This group has been known for a long time in Vermont by the name of Red Sandrock. * * * Below the Potsdam sandstone lie great masses of slate, four or five thousand feet thick, which for convenience I should divide into three parts.[4]

These are the Lingula flags, Georgia slates, and St. Albans group.

The Georgia slates are stated to be characterized by Primordial fossils, notably *Paradoxides* (*Olenellus*) *thompsoni*, *P. vermontana*, *Peltura holopyga*, *Obolella cingulata*, etc.[5]

In noting the discovery of fossils in the Winooski marble, at Swanton, Vermont, Mr. E. Billings[6] states that fossils were discovered by Mr. Solon M. Allis, of Burlington, Vermont, who sent them to him for ex-

---

[1] Geological Survey of Canada; report of progress from its commencement to 1863. Montreal, 1863, pp. 281, 282.

[2] Op. cit., p. 282.

[3] The Taconic and Lower Silurian rocks of Vermont and Canada. Boston Soc. Nat. Hist. Proc., vol. 8, 1862, pp. 239–253.

[4] Op. cit., p. 244. [5] Op. cit., p. 245.

[6] Note on the discovery of fossils in the "Winooski marble," at Swanton, Vermont. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 145, 146. Canadian Nat., new ser., vol. 6, p. 351.

amination. He found a species of Salterella, which he identified as *Salterella pulchella.* He observes that the Winooski marble, both at Swanton and St. Albans, seems to underlie the Georgia slates, and he says:

It is generally of a reddish, mottled color, but sometimes gray or greenish. The limestone at the Straits of Belle Isle, in which *S. pulchella* is found, is also red, gray, and greenish; and is, I have no doubt, of the same age. At this latter locality it overlies a red or brownish sandstone, conformably, which holds *Scolithus linearis.* I consider the Belle Isle sandstone to be the "Quartz rock" of the Green Mountains of Vermont. In that case, the limestone at Belle Isle occupies, stratigraphically, the position of the Stockbridge limestone as represented by Dr. Emmons in his American Geology, part 2, p. 19.[1]

Under the title "Geology of Vermont," Prof. C. H. Hitchcock tabulates the formations of that State.[2] The Potsdam group is made to include the Red Sandrock, part of the Hudson River slate, part of the Georgia slate, most of the quartz rock, and the Potsdam sandstone of West Haven. Speaking of the latter he says, the Potsdam rocks flank the gneiss upon the west side as far north as Middlebury. He further observes that the quartz rock is probably the same as the red sandstone; that both are overlain by the Levis[3] limestone, and resemble each other very much near their supposed union. "I find this view of the identity of those two formations confirmed by the late map of the Canadian survey, published in 1866."

In an article on some points in the Geology of Vermont, Dr. T. S. Hunt states:

It happens, then, from the facts already set forth, that the Potsdam formation, which at its outcrop at the foot of the Adirondacks and Laurentides includes only from 300 to 700 feet of sandstone, is represented a few miles to the eastward by not less than 2,000 feet of dolomites, sandstones, and slates, and moreover that occupying a position between the calciferous and chazy formations, which are contiguous at their eastern outcrop, there becomes intercalated within this short distance a fossiliferous group, several thousand feet in thickness.[4]

The explanation of this is quoted from Logan's opinion, to the effect that the Potsdam sandstone accumulated along the shore, while shales and limestones were accumulating to a greater thickness in the deeper water of the adjacent ocean. In summing up the evidence as to the age of the rocks of western Vermont he says:

All the evidence, paleontological and stratigraphical, as yet brought forward affords no proof of the existence in Vermont of any strata (a small spur of Laurentian excepted) lower than the Potsdam formation, which the present advocates of the Taconic system regard as forming its summit. * * * That strata still older than the Potsdam of New York and Vermont were deposited in some portions of the oceanic area is apparent from the existence in New Brunswick of the St. John's slates holding a Primordial fauna older than the Potsdam, and it is not impossible

[1] Op. cit., p. 351. [2] Am. Assoc. Proc., vol. 16, 1867, p. 120.

[3] Levis group, including the "Eolian limestones," "Hudson River limestones," and the greater portion of the Georgia slate. (Op. cit., p. 120.)

[4] On some points in the geology of Vermont. Am. Jour. Sci., 2d ser., vol. 46, 1868, p. 225.

that their equivalents may underlie the Potsdam formation of Vermont. No such rocks, have, however, as yet been detected in either Vermont or Canada.[1]

That Dr. Hunt also confounded the typical Potsdam sandstone of the Adirondacks, the quartzite of the western base of the Green Mountains, and the Primordial series described by Murray in Newfoundland is shown by his statement that a few hundred feet of typical Potsdam sandstone in New York are represented in Vermont, Quebec, and Newfoundland by thousands of feet of strata lithologically very unlike the type.[2]

In 1867 Prof. C. H. Hitchcock identified the Winooski marble of Vermont as the Red Sandrock, and stated that *Olenellus thompsoni* and *O. vermontana* occurred in the superjacent slaty layers.[3] In the same volume he presents a table of the strata from the Silurian to the Devonian, inclusive, as found in Vermont, and in this connection he says he considers the Taconic to be of Lower Silurian age. This included, as described by Emmons, the Georgia slates.[4]

At the time of the presentation of the two foregoing papers by Prof. Hitchcock a paper on the Red sandrock of Vermont and its relations was read by Mr. J. B. Perry.[5] He concluded that the Red sandrock was equivalent to the Potsdam, and that the sedimentary beds below the Potsdam were not Utica or Lorraine, but belong to the Primordial zone of Barrande. The Potsdam is considered to be the top of the Primordial, not the base of the Silurian. In the table of formations the Red sandrock or Potsdam is placed at the top of the Taconic system, and the Taconic slate with the quartzite limestone or conglomerate at the base. The following year the same author[6] again stated that the Red sandrock was of Potsdam age and not Medina, and he subdivided the slates below into the Swanton and Georgia series, as older than the Utica slate, referring them to the Primordial of Barrande.

In a summary of the Geology of Vermont, by Prof. C. H. Hitchcock,[7] published in connection with the Geology of Northern New England, it is stated, under the head of "Potsdam Group," that it includes (1) black slate, or part of the "Hudson River slate" of the former report of the Vermont Survey. (2) Georgia slate. (3) Red Sandrock and quartz rock at the base of the Green Mountains. (4) Potsdam sandstone, the same as the original beds in New York.

---

[1] Op. cit., p. 229.

[2] On the geology of eastern New England. Am. Jour. Sci., 2d ser., vol. 50, 1870, p. 85.

[3] The Winooski marble of Colchester, Vermont. Am. Assoc. Proc., vol. 16, 1867, p. 119.

[4] The Geology of Vermont. Am. Assoc. Proc., vol. 16, 1867, p. 122.

[5] Am. Assoc. Proc., vol. 16, 1867, pp. 128–134.

[6] Queries on the red sandstone of Vermont and its relations. Boston Soc. Nat. Hist., Proc., vol. 11, 1868, pp. 341–353.

[7] The geology of Vermont. In Geology of northern New England, 4to, 1870, p. 2.

The Red sandrock is described as extending from St. Armand, province of Quebec, to Bridport, Vermont.

The brightest red rocks are found along the western border; so that while the alliance of the red rock of Burlington and the quartzite of Bennington seems incongruous, it is otherwise with the reddish rocks of Monkton and the brown quartz of Starksboro' and Bristol.[1]

It is stated that the name Georgia was applied to the group of slates carrying Olenellus. It was then supposed that the slates were entirely distinct from the sandstones, but further investigation has shown an interstratification, with the presence of the characteristic trilobites throughout the beds.

Of the "Granular Quartz" on the western slope of the Green Mountains he says:

No rock can be more distinct from all others than the quartzite from the State line north to Starksboro', consisting chiefly of pure vitreous silica, sometimes hardly showing a sedimentary composition. * * * The group makes a mountain range throughout, some of the peaks exceeding 3,000 feet in height. * * * An abundance of *Scolithus linearis* appears in this formation, and the rock was referred to the Potsdam in 1841 by H. D. Rogers and W. B. Rogers, in opposition to E. Emmons, who subsequently called it "granular quartz," lying at the base of the Taconic system, thousands of feet below the former.[1]

In 1871 Mr. S. W. Ford[2] published an account of a section of rocks at Troy, New York, in which he had found the Olenellus fauna. In 1884, he added[3] a description of a section near Schodack Landing, south of Troy, in Columbia County, New York. By the contained fauna the strata were correlated with those described by Sir William Logan, in Vermont, Canada, and Newfoundland.

Prof. J. D. Dana,[4] from 1872 to 1877 worked out, with considerable detail, the stratigraphic relations of the "Granular Quartz," of Berkshire County, Massachusetts, to the subjacent Archean and the superjacent Silurian limestone, adding many details to the general outlines published by Messrs. Eaton, Dewey, and Emmons. In the description of the quartzite, limestone, and associated rocks of Great Barrington, Berkshire County, Massachusetts,[5] it is stated that the quartzite of Great Barrington alternates with mica schist, and that both of the rocks for the most part overlie the Stockbridge limestone. Of the Green Mountain quartzite, Prof. Dana says:[6] "In the first place there are quartzites of more than one age in New England, west of the Connecticut River." A

[1] Op. cit., p. 3.

[2] Notes on the Primordial rocks in the vicinity of Troy, New York. Am. Jour. Sci., 3d ser., vol. 2, 1871, pp. 32–34. Can., Nat., new ser., vol. 6, 1872, pp. 209–212.

[3] On the age of the glazed and contorted slaty rocks in the vicinity of Schodack Landing, Rensselaer County, New York. Am. Jour. Sci, 3d ser., vol. 28, 1884, pp. 206–208.

[4] Green Mountain geology. On the quartzite. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 179–186, 256. An account of the discoveries in Vermont geology of the Rev. Augustus Wing. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 332–347, 405–419; vol. 14, pp. 36–37, 1877.

[5] On the quartz, limestone and associated rocks of the vicinity of Great Barrington, Berkshire County, Mass. Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 362.

[6] Green Mountain geology. On the quartzite. Am. Jour. Sci., 3d ser., vol. 3, 1872, p. 181.

Helderberg quartzite exists at Bernardston, Massachusetts, and another quartzite of different age, about 3 miles west of Plymouth, Vermont, is interstratified with gneiss; and then there is the great quartzite of the Green Mountain range, whose relation to the quartzites interbedded in the gneiss is unascertained. "We can not assume, therefore, that this last is all of one geological age." After examining the quartzite of Canaan, Connecticut, he was led to the conclusion from the facts observed that the quartzite is the inferior rock, and rests unconformably beneath the limestone.[1]

When briefly presenting some conclusions concerning the stratigraphical structure of the Cambrian of western Vermont, Prof. C. H. Hitchcock[2] states that Dr. Emmons believed the rocks were deposited against the western base of the Green Mountains, in order of, first, the Granular Quartz, then the Stockbridge limestone, and lastly the various slates which were capped by the black slates holding Olenellus. The report says further:

Prof. Hitchcock suggested as a better theory of structure, that sediments were formed contemporaneously, both upon the Green Mountains and the Adirondack side of the valley, thus making the granular quartz on the east side of the valley of the same age with the Potsdam sandstone at Whitehall, N. Y., and elsewhere west of Lake Champlain. Next, the Calciferous sandstone, Levis, Chazy, and Trenton limestones, were deposited entirely across the valley and by means of their fossils are now identified adjacent to both the quartz rock and the typical Potsdam sandstone. Thirdly, the limestones are succeeded by slates. This theory of original deposition differs from that of Emmons, in supposing that sedimentation was being effected both on the Green Mountain and Adirondack borders, instead of on the former only.[3]

In summing up the account of the discoveries of Rev. Augustus Wing in Vermont geology, Prof. Dana says:[4]

The Red sandrock on the west of the Eolian limestone—admitted to be Potsdam or Primordial in age—and the Quartzyte on the east which often rises into mountain ridges, are of the same formation, and come nearly or quite together in Monkton, on the northern limits of the limestone area (p. 414).

The quartzyte of the eastern range, with that also of the local belts in the Eolian limestone area, is regarded as Potsdam (or Primordial) in age, because it contains in many places *Scolithi* (worm-burrows) and *Fucoids* like those found in the Potsdam sandstone; because also it adjoins Calciferous limestone beds at the localities just mentioned in North Middlebury and New Haven; and because it joins the Red sandrock in Monkton, and one rock has in many places the character of the other, although not commonly alike in color, and showing differences explainable on the ground of the greater metamorphism of the quartzyte. "In Monkton, the Red sandrock and the Quartzyte meet in a succession of short anticlinals, thus cutting off to the north the great trough or synclinal;" and "the Red sandrock absolutely overlies the beds of Red sandrock in one anticlinal and the quartzyte in another anticlinal, and both hold *Scolithus linearis*."[5]

[1] Op. cit., p. 183.

[2] Remarks on the stratigraphical structure of the Cambrian and Cambro-Silurian rocks of western Vermont. Boston Soc. Nat. Hist., Proc., vol. 18, 1875, p. 191.

[3] Op. cit., p. 191.

[4] An account of the discoveries in Vermont geology of the Rev. Augustus Wing. Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 414–416; vol. 14, pp. 36–37.

[5] Op. cit. p. 416.

Dr. T. S. Hunt, in 1878,[1] gives an historical review of the rocks referred to the Cambrian and Taconic systems and in this way speaks of the "Upper Taconic" and refers it to the Cambrian, and the "Granular Quartz" to an Archean system. Again, in 1883,–'84,–'86, he went over the same ground,[2] but did not add any original information upon the subject. He adopted the view of Prof. Eaton so well expressed in the section of 1824, and brought down to 1886 the erroneous view of the unconformity between the Calciferous sandrock and the Argillite. To the strata which Dr. Emmons included in the Taconic system, in 1842, he gave the name Taconian, referring them to a pre-Cambrian, Archean, group of rocks.

In a paper upon the colonies in the Taconic rocks of the borders of Lake Champlain,[3] Prof. Jules Marcou gives a résumé of his investigations in northern Vermont up to date. In the vertical section accompanying the geological map, the Potsdam sandstone is placed at the summit of the upper Taconic series, and then in order below, the Swanton schists, Phillipsburg group, Georgia schists, and the St. Albans group. On sections in the text the Potsdam sandstone is represented as unconformably superjacent to the Georgia slates, the Phillipsburg group, and the Swanton schists, and the St. Albans group. A general description is given of the formations as interpreted by Prof. Marcou. As now known the Potsdam sandstone as identified by him, is the Red sandrock of the Vermont geologists, or the arenaceous magnesian limestone of Logan. Its stratigraphical position is at the base of the series described, or at the base of the Lower Cambrian as now understood.

A series of geological sections across Vermont and New Hampshire by Prof. C. H. Hitchcock[4] have the Red Sandrock series marked as Potsdam and the Georgia slate series as Cambrian. The Granular Quartz of the southern portion of Vermont is all marked Potsdam. In the text[5] Prof. Hitchcock says:

> Three bands of sandstone therefore are referred to the Potsdam in the Champlain valley: first, the normal gray sedimentary beds at the foot of the Adirondacks always known under this name since 1840; second, the quartzite on the flank of the Green Mountains; third, a range of red sandstone and dolomite from the Canada line to Bridport, where it is succeeded by outcrops of a material not distinguishable from the first named band. Partly accompanying the middle band is a series of slates and hard sandstones, passing into roofing slates called the Georgia group in the State report, which carries such fossils as Olenellus and Angelina, and is, therefore, thought to be somewhat older than the typical Potsdam sandstone.

In the same publication Prof. R. P. Whitfield[6] states it to be his

[1] Special report on the trap dikes and azoic rocks of southern Pennsylvania. 2d Geol. Surv. Pa., E. 1878, p. 253.

[2] The Taconic question in geology. Mineral Physiology and Physiography. A second series of chemical and geological essays, with a general introduction. 1886, pp. 517–686.

[3] Sur les colonies dans les roches taconiques des bords du lac Champlain. Soc. géol. France, Bull. 3me sér, vol. 9, 1880, pp. 18–46.

[4] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, pp. 155–179.

[5] Op. cit., p. 160.

[6] *Notice of some new species of Primordial fossils in the collections of the Museum, and corrections of previously described species.* Am. Mus. Nat. Hist., Bull., vol. 1, 1884, p. 140.

impression that the New York typical Potsdam is about equivalent to the lower portion of the Wisconsin series; and that the Acadian beds of Canada and Vermont, and perhaps the other Atlantic areas, are not appreciably different in age; but the difference in faunæ is more the result of conditions upon which life depended than a difference in time. This generalization of Prof. Whitfield placed the "Granular Quartz," "Red sandrock" or dolomite, Georgia slate and the Potsdam sandstone of New York and the Upper Mississippi Valley in one geologic horizon, the equivalent of the lower beds of the Mississippi Valley section.

In 1888 Prof. N. H. Winchell[1] correlated the "Granular Quartz" of Emmons's Taconic system with the Potsdam sandstone, and mentions its westward extension in the Mississippi Valley. In another paper[2] he says that the stratigraphical relations of the "Granular Quartz" and the Potsdam of New York are the same; that the fossils are cognate with those of the Red Sandrock and with those that have been found in the Potsdam; that the Red sandrock overlies the Georgia unconformably, and that the stratigraphic relations of the Granular Quartz and the Potsdam sandstone to the granite are the same as those of a Primordial quartzite of the northwest to the granite.[3]

In summing up the opinions of the geological position of the quartzite on the eastern border of the limestone, and between the limestone and the Archean, Prof. J. D. Dana[4] says that he pointed out in 1872 that the quartzite formation in southeastern Dutchess County lay between the limestone and the adjoining Archean, and the same also occurs in other localities; that he inferred from the position and apparent conformability that its age was Potsdam or that of the lowest beds of the Lower Silurian of the region; also, that there is a quartzite west of the border of the limestone that overlies the limestone conformably, and is an independent formation and newer than the limestone. In his stratigraphic conclusions at a later date[5] the Cambrian quartzites are supposed to be those immediately adjacent to the Archean gneiss and equivalent to the Potsdam sandstone, while those that occurred at a horizon above the limestone are supposed to belong to the Hudson period.

In a paper on "The Taconic System and its position in stratigraphic geology" Prof. Jules Marcou[6] tabulates the strata referred to the Taconic system in eastern North America. In this, the Saratoga limestone, with Dikellocephalus is the summit of the series, above the Red sandrock of Vermont and the Potsdam sandstone of Keeseville, New York.

[1] A great Primordial Quartzite. Am. Geol., vol. 1, 1888, pp. 173–178.

[2] The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist., Survey of Minn., 17th Ann. Rep. for 1888, 1889, pp. 5–74.

[3] Op. cit., pp. 49, 50.

[4] On Taconic rocks and stratigraphy, with a geological map of the Taconic region. Am. Jour. Sci., 3d ser., vol. 29, 1885, p. 209.

[5] On Taconic rocks and stratigraphy, with a geological map of the Taconic regions. Part 2. The middle and northern part. Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 408–409.

[6] Am. Acad., Proc., vol. 20, 1885, p. 224.

In order, below, comes the Swanton slates, and the Phillipsburgh or Point Levis group, subjacent to which are the Georgia slates (or Olenellus zone). The Paradoxides zone, the Upper Cambrian or Eophyton sandstone of Great Bell Island, Newfoundland, and the Aspidella and Arenicolites slates of St. John's, Newfoundland, are assembled under the name "St. Albans group."

In this table, under the upper formations or "Potsdam group," there are brought together the summit of the Cambrian (the Saratoga limestone) and the base of the Cambrian (the Red sandrock of Vermont), as well as the Keeseville sandstone, which is the lower portion of the Upper Cambrian. In the "Swanton slates" (Trenton-Hudson terrane) and in the "Phillipsburg or Point Levis group," we have the Calciferous-Chazy zone. The Eophyton sandstone placed beneath the Georgia slates and the Paradoxides beds is the equivalent of the Saratoga limestone placed at the summit of the series. The Aspidella and Arenicolites slates of St. John, Newfoundland, are of pre-Cambrian age. Thus the lower or "St. Albans group" includes pre-Cambrian, Upper Cambrian, and Paradoxides zone strata.

In an article on the Winooski or Wakefield marble of Vermont, Prof. G. H. Perkins[1] described several sections of the strata containing the quarries worked for marble, one of which has a thickness of 1,410 feet, another 790, and another 710 feet. He found *Salterella pulchella* in the marble beds and considered the series to be of Primordial age.

When describing a section in the Cambrian formation of western Vermont in the town of Georgia, Franklin County, Mr. C. D. Walcott[2] stated that the section consisted of a massive belt of limestone 1,000 feet in thickness subjacent to a series of argillaceous shales, at the base of which the Olenellus fauna occurred. He also stated that this section includes in its vertical range the sections above and below Troy, N. Y., in the Hudson River Valley, and those of Newfoundland and the Straits of Belle Isle. This was followed in the same year[3] by a detailed description of the Georgia section, and another section taken near the Canadian and United States boundary in the township of Highgate. At this latter locality the Red sandrock series has a thickness of 1,170 feet; the Georgia slates a thickness of 1,000 feet. A list of the fossils occurring in the strata is given in the tabulated section. Following the nomenclature proposed by Sir William Logan, the Red sandrock series and the Georgia slates are referred to the Middle Cambrian subjacent to the Potsdam sandstone of the Adirondacks, and above the Paradoxides slates of New Brunswick.[4] In the same year he determined by paleontological evidence that the roofing slates of Granville,

[1] Am. Naturalist, vol. 19, 1885, pp. 128–136.

[2] Classification of the Cambrian System of North America., Am. Jour. Sci., 3d ser., vol. 32, 1886, p. 145.

[3] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey Bull. No. 30, 1886, pp. 13–26.

[4] Op. cit., pp. 63, 64.

Washington County, New York, which includes green and purple slates, were of the same geologic age as the Georgia slate.[1]

The extension of the "Granular Quartz" of the eastern part of New York into Dutchess County was described by Dr. W. W. Mather[2] as it occurred about Stissing Mountain. He refers to it as the "Granular Quartz" and Potsdam sandstone. Within a few years Prof. John C. Smock[3] examined the geological structure of the mountain, stating that the quartzite was unconformably superjacent to the Archean rocks; and that no fossils had been found in it. In the description of the Primordial rocks of the Wappinger Valley, by Prof. W. B. Dwight,[4] mention is made of the quartzite about Stissing Mountain, as well as the discovery by himself and Mr. C. D. Walcott of Middle[5] Cambrian remains in the arenaceous quartzite and limestones on the flanks of the mountain. It is thus correlated with the Olenellus beds of the Georgia series of Vermont.

At the Ann Arbor meeting of the American Association for the Advancement of Science, held in August, 1885, Prof. Dwight[6] announced the discovery of fossiliferous Potsdam strata at Poughkeepsie, New York. He says[7]:

> Lithologically, the rock is here very variable. It is everywhere calcareous, all its varieties effervescing freely with acids. It is also everywhere more or less arenaceous, often conspicuously so; from being compact and massive it changes to a rock fissile into thin slabs or to one splitting into the thinnest leaves, which are covered with loose sand as they decompose.
>
> This rock passes on the one hand into a smooth fine-grained, argillaceous limestone, and then into a very fissile calcareous shale or, on the other hand, into a quartzite, somewhat calcareous.

An account of the localities at which the rock occurs and a list of eleven species of fossils are given. This paper was published more in detail in the number of the American Journal of Science for February, 1886, and was accompanied by a map on which the geographic distribution of the Potsdam and related strata are shown.[8]

Prof. Dwight[9] announced in 1889 the discovery of fossiliferous strata

---

[1] Walcott, C. D. Cambrian age of the roofing slates of Granville, Washington County, New York. Am. Assoc., Proc., vol. 35, 1887, pp. 220, 221. (Advance sheets published 1886.)

[2] Natural Hist. of New York. Part 1. Geology of New York; Geology of the first (southeastern) District. Albany, 1843, pp. 418, 423, 436, 437.

[3] A geological reconnoissance in the crystalline rock region, Dutchess, Putnam, and Westchester Counties, New York. Thirty-ninth Ann. Rep. State Mus. Nat. Hist., 1886. pp. 166–185.

[4] Primordial rocks of the Wappinger Valley limestones and associated strata. Vassar Brothers Inst., Trans., vol. 4, 1887, pp. 206–214. Discovery of additional fossiliferous Potsdam strata and pre-Potsdam strata of the Olenellus group near Poughkeepsie, N. Y. Am. Jour. Sci., 3d ser., vol. 34, 1887, p. 27–32.

[5] Now classed as Lower Cambrian.

[6] Discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y., Am. Assoc., Proc., vol 34, 1886, p. 201–209.

[7] Op. cit., p. 205.

[8] Recent explorations in the Wappinger Valley limestone of Dutchess County, N. Y., No. 5. Discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y. (illustrated by map, Plate VI). Am. Jour. Sci., 3d ser., vol. 31, 1886, pp. 125–133. Primordial rocks of the Wappinger Valley limestones Vassar Brothers' Inst. Trans., vol. 4, 1887, pp. 130–141, Plate 1.

[9] Recent explorations in the Wappinger Valley limestones and other formations of Dutchess County, N. Y. Am. Jour. Sci., 3d ser., vol. 38, 1889, pp. 139–153.

of the Paradoxides zone at Stissing, Dutchess County. In the limestone and calcareous shale immediately overlying the Olenellus limestone, at the south end of Stissing Mountain, he discovered a fauna that is correlated with the Middle Cambrian or Paradoxides fauna, thus establishing the middle member of the Cambrian system in addition to the Lower Cambrian and Upper Cambrian that had been previously found in this region. A plate illustrating the fauna accompanies the paper.

In 1887 Mr. C. D. Walcott[1] published a description of the fauna of the Upper Taconic of Emmons, of Washington County, New York. In this a statement of the stratigraphic position of the fauna was made, based on the correlation with the fauna of the Georgia slates of Vermont. This was followed in 1888 by an account of the discovery of fossils in the Granular Quartz near Bennington, Vermont.[2] The discovery was further described in a paper which followed on the Taconic system of Emmons,[3] where an account is given of the mode of occurrence of the "Granular Quartz" in western Massachusetts and Vermont. The quartzite is referred to the Middle (now Lower) Cambrian zone, of which the Olenellus bearing shales of the Georgia section are the type. A description is given[4] of the slates and shales, and it is stated the formations of the Upper Taconic have a thickness of 14,000 feet. In these the Olenellus fauna occurs more or less abundantly at various horizons. An examination of the sections and the fauna of the "Granular Quartz" and "Taconic" shales and slates, shows that the former is stratigraphically and faunally the equivalent of the upper part of the latter; while the "Granular Quartz" is a sandy deposit of the shore line, and the shales and slates the offshore accumulation of sediments. On the map accompanying this paper the geographic distribution of the "Granular Quartz," the "Red sandrock" of Vermont, and the Georgia slates and their southward extension as the Taconic slates is represented.

In a tabular view of the American Classification and Nomenclature, published in 1888, by Prof. Jules Marcou,[5] the Taconic system is divided into upper, middle, and lower divisions. In the upper division the Potsdam sandstone, Swanton slates, Phillipsburg and Point Levis formations are included. The middle division includes the Georgia formation and the St. John or Paradoxides zone, of New Brunswick, of Braintree, Massachusetts, and of St. Mary's Bay, Newfoundland. In the lower division are the Chuar and Grand Cañon formations of the Grand Cañon, Arizona, the sandstones of Great Bell Island, and the slates of St. John's, Newfoundland. The confusion in this table is not

[1] Fauna of the "Upper Taconic" of Emmons, in Washington County, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 187-199.

[2] Discovery of fossils in the Lower Taconic of Emmons. Am. Assoc., Proc., vol. 36, 1888, pp. 212, 213.

[3] The Taconic System of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d series, vol. 35, 1888, pp. 229-242, 307-327, 394-401.

[4] Op. cit., pp. 241, 242.

[5] American Geological Classification and Nomenclature. Cambridge, 1888, p. 75.

as great as that of the 1885 paper. The Swanton slates, of Hudson age, and the Phillipsburgh and Point Levis formation of Calciferous age, are placed with the Potsdam sandstone; while in the Lower Taconic we find the sandstones of Great Bell Island, which are the geologic equivalent of the Potsdam sandstone.

During the summer of 1888 Mr. C. D. Walcott visited Newfoundland and studied[1] a section on Manuel's Brook, Conception Bay, that extends from the Archean gneiss up to the Olenellus and Paradoxides zones. In this unbroken section it was found that the Olenellus fauna occurred at the base and the Paradoxides fauna above. This necessitated a revision of the classification of the Cambrian. The Lower Cambrian with the Olenellus fauna is at the base; next the Middle Cambrian with the Paradoxides fauna, and lastly the Upper Cambrian or Potsdam zone, at the summit of which the Dikellocephalus fauna occurs. This correlation places the "Red Sandrock" series, the Georgia shale and slate series, the "Granular Quartz," and the "Upper Taconic" of Emmons beneath the Middle Cambrian or Paradoxides zone of the Atlantic coast.

In a paper on the fauna of the Olenellus zone[2] a brief historical review is given of the rocks referred to the Olenellus zone in Vermont and eastern New York, and also an account of the sections and the distribution of the fauna.

In a paper read before the Geological Society of America, December 30, 1890, Dr. J. E. Wolff noted the discovery of fossils of supposed Lower Cambrian age in the limestones of the East Rutland Valley, Vermont. The limestones rest conformably upon the basal quartzite carrying the Olenellus fauna.[3]

Potsdam sandstone.—The Potsdam sandstone of the Adirondack area appears only in a few small outcrops in Vermont and eastern New York. According to Prof. C. H. Hitchcock, there are three different localities in Vermont:[4] near the Lake Champlain shore in West Haven, Orwell, and the east part of Shoreham, in the counties of Addison and Rutland. There were none of these of sufficient importance to be indicated on the map of 1877. The outcrops in eastern New York are practically a continuation of the Vermont exposures. They occur in the vicinity of Whitehall, New York, and south to Fort Ann, Washington County.

In the review of the references made to the "Red Sandrock" series of Vermont, frequent mention has been made of its correlation with the Potsdam sandstone as well as of the correlation of the "Granular Quartz" with the Potsdam sandstone of the Adirondack area. As now known, these two belong to distinct geological horizons, as claimed by

[1] The stratigraphical succession of the Cambrian faunas of North America. Nature, vol. 38, 1888, p. 561.

[2] Walcott, C. D. The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geological Survey, 1890, pp. 509–763.

[3] Bull. Geol. Soc. America, vol. 2, 1891, pp. 334–337.

[4] Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 265.

Dr. Emmons in 1842. As the typical Potsdam sandstone in this district is an extension of the sandstone of the Adirondack sub-area within its borders, the review of its literature will be united with that of the typical Potsdam of the Adirondack district.

The occurrence of the Upper Cambrian or Potsdam zone as distinct from the Georgia slate and "Red Sandrock," is spoken of in the description of the section crossing the town of Georgia, Vermont,[1] where mention is made of the discovery of a fauna closely related to that of the Upper Cambrian. This is the same horizon referred to on page 17, par. 14.

In a description of a section crossing the typical Taconic area of eastern New York and western Massachusetts by Mr. C. D. Walcott,[2] the typical Potsdam sandstone is not recognized. It is stated that certain shales designated as Terrane No. 2, may represent the Potsdam terrane, or it may be represented by the lower part of the limestones of Terrane No. 3, or the upper part of the Quartzite of Terrane No. 1.

CANADIAN EXTENSION.

The Canadian extension of the Northern Appalachian District is from the United States boundary northeast to the vicinity of Point Levis, Quebec, on the western side of the extension of the Green Mountain or Sutton Mountain anticlinal, and from Quebec down the south shore of the St. Lawrence River to Cape Rosier, Gaspé. On the eastern side of the anticlinal the supposed Cambrian rocks of New Hampshire, crossing the southeastern portion of the province of Quebec, to the Maine boundary, are also included.

The first notice of the rocks, subsequently referred to the Cambrian in the vicinity of Quebec, was by Dr. J. J. Bigsby.[3] He divided the strata into three series. First, the slaty series, composed of slates and grauwacke, occasionally passing into a brown limestone, and alternating with calcareous conglomerate in beds, some of which are charged with fossils; second, the limestone series; third, gneiss. In the beds of this conglomerate on the south side of the St. Lawrence he noticed the presence of trilobites, encrinites, corallines, and other fossils. He considered them above the supposed equivalent of the Carboniferous limestone of the English geologists.

In his description of the succession of the strata at Montmorenci Falls, Dr. E. Emmons states that the rock forming the falls is a gneiss, and in the figure illustrating the section the Potsdam sandstone is shown resting unconformably upon the gneiss and subjacent to the Trenton limestone, but with a conglomerate between it and the Trenton limestone.[4] He subsequently correlated the sandstones that are extensively

[1] Walcott, C. D. Second contribution to the studies of the Cambrian faunas of North America. U.S. Geol. Survey, Bull. No. 30, 1886, p. 19.

[2] The Taconic System of Emmons and the use of the name Taconic in Geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 240.

[3] On the geology of Quebec and vicinity. Proc. Geol. Soc., London, vol. 1, 1827, p. 37.

[4] Geology of the Montmorenci. The American Magazine, vol. 1, 1841, p. 148.

used in the construction of buildings, both public and private, and in the fortifications of Quebec, with the gray sandstone terminating the Lorraine section of Jefferson County, New York.[1] These sandstones were subsequently named the Sillery sandstones by Sir W. E. Logan, who at first followed the correlation made by Dr. Emmons, and referred them to the Lorraine shales or Hudson River group.

In the report of progress for 1843, of the Geological Survey of Canada,[2] an account is given in a very general manner of an exploration by Sir W. E. Logan of the rocks on the south shore of the lower St. Lawrence, near Cape Rosier; and they are further described in the report for 1844, as seen from Cape Chat toward Cape Rosier, going down the river. This is followed in the report for 1847–'48[3] by a description of the rocks of the extension of the Green Mountains into Canada, and the strata upon the west which are now supposed to be of Cambrian age. They were then referred to the Hudson River group, with the possible addition of the Shawangunk conglomerate. In their extension it is stated[4] that these recognized rocks of the Hudson River group have a continuous run from Lake Champlain along the south bank of the St. Lawrence to Cape Rosier.

In a report on the rocks on the south side of the St. Lawrence, in the report of progress for 1849–'50,[5] a preliminary description is given of five masses of rock met with. They include the dark gray slates, gray, green, and occasionally red shales, hard sandstones, and a red and green shale that were subsequently largely referred to the Quebec group by Sir Wm. Logan, and now, in part, to the Cambrian by Dr. R. W. Ells. In a report for 1852–'53[6] a description is given of the strata on the north shore of the St. Lawrence between Cap Rouge River and Quebec. At the base there is a succession of hard, sandy layers, with softer shales that extend along the river shore for some distance, and then thick beds of sandstone separated by thinner bands of red and green shales. The red and green shales have a great thickness further down the river. Mr. Logan says that it would be hazardous to pronounce with confidence what it is, from the probably contorted condition of the strata. In regard to the sandstones, however (supposed to represent the Oneida conglomerate), no folds have been detected. They are thought to be about 900 feet in thickness. This is the first preliminary description of the sandstones and shales that were subsequently referred to the Lauzon and Sillery series of the Quebec group.[7]

[1] Geology of New York, part 2, comprising the survey of the 2d geological (northern) district. 1842, p. 125.

[2] [Account of the general structure of an extended area in North America.] Geological survey Canada, report of progress for 1843. 1845, pp. 6–13 [Documentary Edition.]

[3] Logan, W. E. Geological survey Canada, report for progress 1847–'48. 1849, pp. 2–17 [Documentary Edition.]

[4] Op. cit., p. 17.

[5] Logan, W. E. [Report on rocks on south side of the St. Lawrence.] Geological survey Canada, report of progress for 1849–'50. Toronto, 1850, pp. 32–33.

[6] Logan, W. E. [Exploration on the north side of the St. Lawrence, between Montreal and Cape Tourmente.] Geological survey Canada, report of progress for 1852–'53, 1854, pp. 5–74.

[7] Op. cit., p. 34.

Dr. J. J. Bigsby,[1] in describing the geology of Quebec and its environs, states that the Potsdam sandstone only occurs distinctly, as far as yet known in the neighborhood, at the Falls of Montmorenci; but at Jeune Lorette there are traces of it. He says that—

> The sandstone of Montmorenci has been unhesitatingly declared to represent the Potsdam rock by the New York State geologists, as well as by Sir Charles Lyell and Mr. Logan. With these high authorities I have only to concur. Its geological position is that of the Potsdam sandstone; but its aspect and mineral condition are very different from that of Lake Superior and of the Thousand Islands, near Kingston, Upper Canada.[2]

In describing the geology of the Falls of Montmorenci, he says:

> The sandstone is plentiful on the east bank of the river above the bridge, and is a yard or more thick, as well as on the west bank both above and below the bridge; the plane of contact with the enclosing rock being clean and abrupt. It is white, brownish red or bright green, in well defined layers. Bowlders of the gneiss occur in it.[3]

A section is introduced in which the Potsdam sandstone is represented as beneath the Trenton limestone, and with the latter resting unconformably against the gneiss. It is stated that the Potsdam sandstone at this place has not yet been found to contain organic remains.

Dr. Bigsby described the north shore of the St. Lawrence, from Quebec to Cap Rouge, as consisting of frequent alternations of gritty gray sandstone, and red, brown, and black clay shale. On the south side of the St. Lawrence, near Point Levis, the rocks are stated to be formed of minute alternations of clay-slate, coarse sandstone, calcareous and other conglomerates that were met with on the north side of the river.[4]

In the report of progress for 1852–'53, published in 1854, Sir W. E. Logan[5] describes the red and green shales and green sandstones from Cap Rouge to Quebec, considering them to belong to the Hudson River group of the New York section.

In a description of the Silurian rocks of the environs of Quebec, the same writer[6] states that the only exposure of the Potsdam formation in the vicinity of Quebec is at Lorette, where the sandstone is 7 metres in thickness and without the fossils which characterize the formation in other parts of Canada. The shales and sandstone of the Sillery formation are stated to correspond to the conglomerates of the Oneida formation of the New York geologists. This same view was expressed in the geological essay prepared for the Paris Exposition of 1855 by Messrs. Logan and Hunt.

From the collections of fossils made by the Geological Survey of Canada at Point Levis during the years 1856–'57, Mr. E. Billings, paleon-

---

[1] On the geology of Quebec and its environs. Quart. Jour. Geol. Soc., vol. 9, 1853, pp. 82-101.

[2] Op. cit., p. 84. [3] Op. cit., p. 88. [4] Op. cit., pp. 94, 95.

[5] (Exploration on the north side of the St. Lawrence, between Montreal and Cape Tourmente.) Geol. Surv. Canada, report progress for 1852–'53, 1854, pp. 33, 34.

[6] (Sur la formation silurique des environs de Québec.) Soc. géol. France, Bull., 2e sér., vol. 12, 1855, p. 505.

tologist of the survey, decided that the rocks there and those which had been associated with them by Sir William E. Logan belonged at the base of the Lower Silurian and not at the summit, as had hitherto been held. These conclusions were announced by Logan in a letter to Mons. J. Barrande published in 1860.[1] In this letter the whole Quebec group, from the base of the magnesian conglomerate with their accompanying magnesian shales, to the summit of the Sillery sandstone, is stated to have a thickness of perhaps from five to seven thousand feet. It appears to be a great development of strata at about the horizon of the Chazy and Calciferous of the New York section.

He says he is not prepared to state that a typical form of the Potsdam sandstone is present where the shales are in greatest force.

> Neither am I prepared to assert its absence, as there are in some places masses of granular quartzite, not far removed from the magnesian rocks of the Quebec group, which require farther investigation; but, from finding wind-mark and ripple-mark on closely succeeding layers of the Potsdam sandstone where it rests immediately upon the Laurentian series, we know that this arenaceous portion of the formation must have been deposited immediately contiguous to the coast of the ancient Silurian sea, where part of it was even exposed at the ebb of tide. Out in deep water the deposit may have been a black, partially calcareous mud, such as would give the shales and limestones which come from beneath the Quebec group.
>
> In Canada no fossils have yet been found in these shales, but the shales resemble those in which *Olenus* have been found in Georgia (Vermont). These shales appear to be interposed between eastward dipping rocks equivalent to the magnesian strata of the Quebec group, and they may be brought up by an overlapping anticlinal or dislocation. We are thus led to believe that these shales and limestones, which may be subordinate to the Potsdam formation, will represent the true Primordial zone in Canada.[2]

In 1863 Sir Wm. E. Logan published his great résumé of the work done by the Geological Survey of Canada from its commencement to 1863.[3] He describes the northward extension of the Georgia series and Red Sandrock of Vermont into Canada, stating that they had been traced but a short distance when they become faulted out and replaced by a later formation.[4]

The Sillery shales and sandstones, as well as the conglomerate beds of Point Levis, Quebec, are described in detail and assigned to about the horizon of the Calciferous-Chazy formations of the New York section. The Levis and Sillery formations are referred to the Quebec group, and the latter series is traced southwestward along the western base of the Sutton Mountain range. The Levis formation is divided into seventeen parts, consisting of alternating calcareous shales, argillaceous shales, limestone conglomerate, and gray sandstone. The upper beds consist of

---

[1] Logan, W. E. Remarks on the fauna of the Quebec group of rocks and the Primordial zone of Canada. Canadian Naturalist, vol. 5, 1860, p. 475; vol. 6, 1861, pp. 106–120; Am. Jour. Sci., 2d ser., vol. 31, 1861, pp. 216–220. Remarques sur la faune des roches du groupe de Québec et sur la zone primordiale du Canada, Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 309–314.

[2] Am. Jour. Sci., 2d ser., vol. 31, p. 219.

[3] Geological Survey of Canada. Report of progress from its commencement to 1863. Montreal, 1863, pp. 983.

[4] Op. cit., p. 285.

red and green shales with thin layers of gray sandstone or quartzite in which Lingula and Obolella were found. At the summit of the red and green shales, interstratified sandstones appear and succeed the shales, with a thickness of about 2,000 feet, forming the Sillery division of the Quebec group (p. 232). Subsequently he[1] divided the Quebec group into three parts: Levis or lower; Lauzon or middle; and Sillery or upper. The Lauzon or middle division embraces the red, green, and purple slates of the section above and below Quebec and on the island of Orleans. The only fossils known were *Obolella pretiosa* and fragments of Lingula. The sandstones and accompanying shales of the original Sillery were referred to the Sillery or upper division with the exception of those separated to form the Lauzon. The Levis, or lower division, was distinguished by its yellow, dark and black shales and the presence of numerous graptolites and Calciferous-Chazy fossils.

Up to this time none of the rocks of the Quebec group had been referred to the Cambrian system, or to an equivalent formation, beneath the Calciferous zone of the New York series. Messrs. Billings, Hall, and Barrande spoke of the Primordial character of some of the fossils of the Point Levis conglomerate, but the series as a whole was referred by Mr. Logan to the Calciferous-Chazy zone.

Sir W. E. Logan also described the conglomerate beds of Bic Harbor and Trois Pistoles on the shore of the St. Lawrence River, where bowlders of limestone were found containing fossils of the Olenellus fauna.[2] The shales in which the bowlders occur are supposed at the present time to be of Upper Cambrian age.

The report on the south shore of the St. Lawrence River below Quebec, by Mr. James Richardson, contains the information that another series of rocks came to the surface, differing from those farther to the west. He says:

> These rocks have heretofore been classed with those of the Quebec group, but they appear to underlie them unconformably, and being in some places marked by fossils which Mr. Billings considers to be of Potsdam age, they are now placed in the upper part of the Potsdam group.[3]

They consist at the summit of a light drab quartz rock with intercalated beds of conglomerate holding limestone pebbles in an arenaceous matrix, the whole forming a series 600 feet in thickness. This is superjacent to a series of gray sandstones and interstratified shales with a thickness of 700 feet in which near the base a conglomerate occurs; below this a third division of gray limestones and limestone conglomerate occurs in beds of from 1 to 6 inches thick. A species of Salterella was observed in the limestone, and a species of Archæocyathus in the shales. The third series is assigned a thickness of 700 feet; and the

[1] Logan, W. E., Report of, for 1866. Geol. Survey Canada, report of progress from 1863 to 1866, 1866, p. 4.

[2] Geological Survey of Canada, report of progress from its commencement to 1863. Montreal, 1863, *p. 260.*

[3] *Report* on the south shore of the St. Lawrence, below Quebec. Geol. Survey Canada, report progress *for 1866*, to 1869, 1870, p. 120.

entire section 2,000 feet. A number of species of the Olenellus fauna were found in the pebbles of the conglomerate near St. Denis Station on the Grand Trunk Railway, and also at Bic Harbor.[1]

The reference by Mr. Richardson of the rocks mentioned in the preceding paragraph to the Potsdam zone is objected to by Dr. A. R. C. Selwyn.[2] He says that after examining a considerable portion of these supposed Potsdam rocks, there is in his opinion at present no sufficient evidence, either paleontological, stratigraphical, or mineralogical, for separating this belt from other very large areas of the Quebec group, hitherto assigned, the larger part to the Lauzon, but in some places also to the Levis and Sillery formations. He states that on any map now published it is best to include the whole of the rocks of this great fossiliferous belt in one group, as the data are insufficient to separate the Potsdam zone from the other rocks of the Silurian. The group referred to is No. 1,[3] the Lower Silurian. The second is "the volcanic group, probably Lower Cambrian." Group No. 2 is described as consisting of a great variety of crystalline, subcrystalline, and altered rocks, including red, gray, and greenish siliceous slates and argillites, great masses of diorite, epidotic and serpentinous breccias and agglomerates, etc.[4] Of the age of this group he says:

> If fossils are found I should expect them to indicate a lower horizon than the Levis formation, probably not far removed from that of the St. John group and Atlantic coast series of Nova Scotia, or Lower Cambrian.[5]

This series forms part of the Sillery formation of Mr. Logan.

In speaking of the reference of the Volcanic group to the Cambrian Dr. Selwyn quotes from the paper read before the Royal Society of Canada in May, 1882, as follows:[6]

> The upper portion of this series was designated "the volcanic belt" from the association with it, especially on the southeast side of the main axis, of a great variety of what were considered to be altered eruptive and irruptive rocks, but whether the strata forming this igneous belt are more nearly allied to the Lower Cambrian than to the Upper Huronian is not, fossils being absent, easily determined.

On the map of the Dominion of Canada geologically colored from surveys made by the Geological Corps from 1842 to 1882, under the direction of Dr. Selwyn, there is quite a broad belt of rocks colored Cambrian that extends from Cape Rosier on the Gaspé Peninsula southeasterly along the shores of the St. Lawrence to Point Levis, Quebec. From Point Levis it turns more to the south, extending along the western margin of the Archean anticlinal to Missisquoi Bay, at the foot of Lake Champlain. A narrower strip is represented as extending

---

[1] Op. cit., p. 130.

[2] Report of observations on the stratigraphy of the Quebec group and the older crystalline rocks of Canada. Geol. Survey Canada, report of progress, 1877-'78, 1879, p. 4A. Can. Nat., new ser., vol. 9, 1879, pp. 17-31.

[3] Op. cit., p. 3A. [4] Op. cit., p. 5A. [5] Op. cit., p. 6A.

[6] Notes on the geology of the southeastern portion of the Province of Quebec. Geol. Survey Canada, report of progress, 1880-'81-'82, 1883, p. 2A.

from the north end of the Archean anticlinal or axis, along the eastern side of the latter to Lake Memphremagog. A smaller area is colored Cambrian in the southeastern part of the Province of Quebec, near the Maine boundary, at the northeastern corner of New Hampshire. In a map of a part of the Province of Quebec published in 1887, the distribution of the Cambrian about the Sutton Mountain anticlinal, or the Archean axis, extending north from the Green Mountains, is given more in detail than in the map of 1882.

In the table of the geological formations, accompanying Macfarlane's American Geological Railway Guide, Dr. T. S. Hunt places the following groups in the Lower Cambrian, in descending order:[1]

Potsdam.
Sillery.
Acadian (Menevian).
Lower Taconic.

This same nomenclature is followed in the list of the geological formations of Canada on page 52.

In a report on the explorations and surveys in the interior of the Gaspé Peninsula, Mr. A. P. Low[2] states that the Cambrian system is represented along the Ste. Anne River and along the east and west flanks of Table-top Mountain, by gray and black shales, limestones, and limestone-conglomerates of the Levis formation. He says:

> These form but a small part of the great area of these rocks, which stretches from Cape Rosier along the south side of the Gulf of St. Lawrence to Quebec and thence through the Eastern Townships into the United States.

In describing the Silurian rocks on a previous page[3] he says the limestones rest in places upon a pinkish or gray sandstone of no great thickness, which is seen on the Ste. Anne and Matane Rivers and on the west side of Lake Matapedia. This sandstone is supposed to be the lowest part of the system.

In his surveys of the eastern portion of the Province of Quebec, Dr. R. W. Ells[4] included in the Cambrian the extension to the northeast of those rocks described as Cambrian by Dr. Selwyn. As described in the reports of the Geological Survey of Canada for 1886, 1887, they consist for the most part of hard quartzite interstratified with mica schists and black slates. Dr. Ells also referred the trappean rocks of Broughton to the Cambrian. All of this series, as described by Dr. Selwyn and Dr. Ells, is unconformably overlapped by the Sillery red slates, conglomerates, and sandstones. It is not improbable that some of the strata referred to the Lower Cambrian may prove to belong to that system of rocks, but in the absence of fossils it is very uncertain whether the strata

[1] Dominion of Canada. (Geological Formations.) Macfarlane's Am. Geol. R. R. Guide, 1870, p. 51.

[2] Explorations and surveys in the interior of the Gaspé Peninsula, 1883. Geol. Surv. Canada, 1882-'83-1884, p. 14F.

[3] Op. cit., p. 12F.

[4] Second report on the geology of a portion of the Province of Quebec. Geological Survey Canada, *new ser.*, *vol.* 3, 1889, pp. 1K-120K.

under consideration should be referred to the Cambrian or to some of the pre-Cambrian series of rocks. In a review of Dr. Ells's work by Mr. C. D. Walcott[1] it is suggested that from the occurrence of Lower Cambrian fossils (the Olenellus fauna) in grayish limestone interbedded with purple, green, and black slates, in Washington County, New York, the rocks containing them occupy a similar stratigraphic position to those described by Dr. Ells in the Canadian section. Dr. Ells considered that portions of the strata referred to the Lower Cambrian are very much like those of the gold series of Nova Scotia, while, in part, they resemble the Cambrian of New Brunswick. Stratigraphically they occupy a position between the chloritic and micaceous schists of the Archean and the superjacent Sillery.[2]

The Canadian extension of the rocks referred to the Cambrian System by Prof. C. H. Hitchcock in New Hampshire is represented upon the geological map of Canada, published by Sir William E. Logan in 1864 as the Quebec group, thus being identified with the Quebec group series upon the western side of the Gaspé limestone series. References have been made to them by various authors who have written upon the geology of the townships of eastern Quebec, but not in a manner to distinguish the strata now referred to the Cambrian.

When describing this belt of rocks in 1886, Dr. R. W. Ells[3] states that Prof. Hitchcock has referred a belt composed principally of blackish, wrinkled slates and schistose sandstones, which form a ridge extending northeast from the vicinity of Canaan, between Hall's and Indian streams to the Quebec boundary, to the Lower or Cambrian system. The strata present a well defined anticlinal structure, which is recognized in the adjoining townships of Emberton and Ditton in Quebec, and northeast past the outlet of Lake Megantic and onward to the Maine boundary. The slates are penetrated by quartz veins, which in places have proved more or less auriferous.

In character and aspect the gold-bearing slates of Ditton and the area to the northeast almost exactly resemble, as already intimated, the rocks of the Nova Scotia gold series.[4]

As far as known no fossils have been found in this series to identify the horizon, in either New Hampshire, Canada, or Maine. This is true also of the second area inclosed on either side of the Stoke Mountains and the Sherbrooke anticlinal. The strata forming the western area west of Sutton Mountain anticlinal have already been mentioned.

The presence of rocks of supposed Cambrian age is indicated on the geological map of Canada, published in 1882, on the eastern side of Hudson's Bay, near the mouth of Big Whale River, and in the vicinity

[1] A review of Dr. R. W. Ells's second report on the geology of a portion of the Province of Quebec, with additional notes on the "Quebec group." Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 101-115.

[2] Ells, R. W. Second report on the geology of a portion of the Province of Quebec. Geol. Surv. Canada, vol. 3, 1889, p. 87K.

[3] Report on the geology of a portion of the eastern townships of Quebec. Geol. Surv. Canada, 1886, new ser., vol. 2, 1887, pp. 24J, 25J.

[4] Op. cit., p. 25J.

of Richmond Bay. The observations upon which this identification is based were made by Dr. Robert Bell, who explored the east coast of Hudson Bay in 1877. He names the series the Manitounuck group, correlating it with the Nipigon series north of Lake Superior. By combining the sections of slates and sandstones he obtains a thickness of 2,800 feet for the entire section on this part of the coast.[1]

References to the occurrence of rocks of supposed Cambrian age on Lakes Mistassini and Mistassinis are made by Mr. A. P. Low in his report on the Mistassini expedition. The limestones, owing to the absence of any fossil remains, have been referred to the Cambrian horizon on account of their lithologic resemblance to Cambrian rocks of the east side of James Bay.[2]

A map of Lake Mistassini accompanies the report, on which the boundary between the Laurentian and supposed Cambrian formations is traced.

Dr. George M. Dawson tabulates the formations; he refers to the Cambrian in Ontario and Quebec as follows:[3]

3*b*. Sillery and Levis.
3*a*. Calciferous.
2*c*. Upper and Lower Potsdam.
2*b*. Keweenian.
2*a*. Animikie.

SOUTHERN APPALACHIAN DISTRICT.

The Southern Appalachian district includes the outcrops of strata referred to formations of the Cambrian group in northern and central New Jersey, southeastern and southern central Pennsylvania, western Maryland, Virginia, and North Carolina, eastern Tennessee, northwestern Georgia, and northeastern Alabama.

NEW JERSEY.

In a table showing the geologic succession of the lower Secondary or Appalachian rocks as they occur in New Jersey, Prof. Rogers[4] places as No. 1 of the series of formations a compact and very quartzose sandstone, of light bluish gray color, approaching to white. He discovered the formation in only three or four small isolated areas along the western outcrops of the Primary rocks. Prof. Cook refers to this sandstone lying upon the gneiss as the "Potsdam sandstone" as known in New York. It is only a few feet in thickness.[5] In a subsequent report a sketch is given of a section at Franklin Furnace, which shows the sand-

[1] Report on an exploration of the east coast of Hudson's Bay, 1877. Geol. Surv. Canada, Rep. Prog. for 1877-78. 1879, p. 17C.

[2] Report of the Mistassini Expedition, 1884-'85. Geol. and Nat. Hist. Surv. Canada, new ser., vol. I, 1885, p. 31D.

[3] Macfarlane James: An American Geological Railway Guide. Second ed., 1890, p. 58.

[4] Description of the Geology of the State of New Jersey, being a final report. Philadelphia, 1840, p. 45.

[5] Report of Prof. George H. Cook upon the geological survey of New Jersey, and its progress during the year 1863. 1864, p. 6, par. 9.

stone resting unconformably on the gneiss and passing conformably beneath the superjacent Magnesian limestone.[1] There are also doubtfully included under the "Potsdam sandstone" several outcrops of quartzite and conglomerate, and the conglomerates and sandstones of the Green Pond Mountain range. On the large geological map of northern New Jersey, published in 1874,[2] the "Potsdam sandstone" includes shales, sandstones, slaty grits, quartz rock, and the Green Pond Mountain conglomerate; this entire series is represented by one color, extending on the trend of the Green Pond Mountain range from the New York boundary southwesterly into the central portion of Morris County.

In the annual report for 1884 the Green Pond Mountain rocks are included with the "Devonian and Silurian rocks."[3] This leaves the so-called "Potsdam sandstone" as the only Cambrian formation within the State. The following year reference is made by Prof. Cook[4] to the contact phenomena with the Paleozoic rocks. In New Jersey one point is at "Owen's Island," in Sussex County, two-thirds of a mile south of the State line, as described by Prof. Rogers in his report of 1836. At this point the sandstone dips 20° northwest, and the Archean 70° to the southwest. Near Franklin Furnace a similar unconformity occurs, and the same conditions appear persistent along the entire northwestern margin of the highlands in New Jersey, though no other actual contact has been observed along this line.

In a paper presented to the Geological Society of America December 31, 1890, Prof. Frank L. Nason stated he had found fossils of Lower Cambrian age in the quartzite resting on the pre-Paleozoic rocks at Hardistonville, Sussex County, New Jersey, and at Franklin Furnace, in the same county. He also discovered fragments of a species of Kutorgina in the superjacent limestone.[5]

DELAWARE.

In the northwestern corner of the State of Delaware there is a triangular area of sandstone referred to the "Potsdam" sandstone by Mr. Fred. D. Chester. He states that it extends into Pennsylvania, and is best exposed beyond the State line.

At Nivin's limestone quarry a mass of quartzite forms what is clearly an anticlinal fold, over which is a corresponding anticlinal of Magnesian limestone.[6]

The extension of this sandstone into Pennsylvania is shown upon the map of Chester County, Pennsylvania, where it occurs in the township of London.

---

[1] Geology of New Jersey. Newark, 1868, p. 72.

[2] Cook, Geo. H. Geological Survey of New Jersey. (Map of) northern New Jersey, showing the iron-ore and limestone districts. 1874, in two sheets.

[3] Cook, Geo. H. Geological Survey of New Jersey. Annual report of the State geologist for the year 1884. 1884, p. 29.

[4] Contact phenomena with the Paleozoic rocks. Geological Survey of New Jersey. Annual Report of the State Geol. for 1885. Trenton, 1885, pp. 53–55.

[5] Unpublished.

[6] Preliminary notes on the geology of Delaware—Laurentian, Paleozoic, and Cretaceous areas. Phila. *Acad. Sci. Proc., vol. 36, 1884, p. 248.*

PENNSYLVANIA.

In the second annual report of the State geologist of Pennsylvania, Prof. H. D. Rogers summarizes in a table the order of stratification, the geographical position, composition, and thickness of the lower Secondary formation in Pennsylvania, east of the Susquehanna River.[1] The description of formation No. I, or the sandstone of the South Mountain, is as follows:

In the ascending order, the first formation which we meet with, reposing on the primary rocks of the South Mountain, * * * is a remarkably compact and rather fine-grained sandstone, usually white or of some light shade of gray. * * * The formation ranges, according to my present belief, from the Delaware, at Easton, more or less interruptedly across the State to the Maryland line, pursuing an undulating, irregular belt, coinciding with the northern and northwestern side of the chain of hills most commonly called in this State the South Mountain, the prolongation of the Highlands of New York and of the Blue Ridge of Maryland and Virginia.[2]

It contains, as far as yet examined in Pennsylvania, very few organic remains, the best defined species discovered in it being a marine plant, indicative of the oceanic position into which the materials of this stratum were originally swept.

I have satisfied myself that this rock is not confined to the Appalachian region of Pennsylvania, but that it possesses a prodigiously extensive range, not only through Maryland and Virginia, but in a contrary direction through New Jersey and New York, and I believe beyond those limits, constituting everywhere the lowermost formation of the widespread Secondary strata which it encircles in a somewhat interrupted belt, following the primary boundary of these rocks from Tennessee to Lake Champlain, and thence northwestward to the northern shores of Lake Huron and Lake Superior [3]

Prof. Rogers recognized the sandstone at many points in New Jersey and New York, and considered it identical with the formation in northeastern New York, described by Prof. Eaton under the name of Calciferous sandrock,[4] and states that it is probably the same stratum which Dr. Bigsby has mentioned as existing on the north side of Lake Huron.[5] In the table showing the order of stratification, formation No. I is assigned a probable thickness of 1,000 feet.

A description is given in the third report[6] of the geographic distribution of the sandstone as it occurs in the various counties of the southeastern portion of the State.

In Northampton and the eastern corner of Lehigh the sandstone * * * is subordinate in importance to the gneiss and other primary rocks on which it rests.[7]

---

[1] Second Annual Report on the Geological Exploration of the State of Pennsylvania. Harrisburg, 1838, oppo. p. 19.

[2] Op. cit., p. 21.

[3] Op. cit., pp. 22, 23.

[4] The Potsdam sandstone was not differentiated from the calciferous sandrock by Eaton. He included the sandstone and the superjacent calcareous sandstone, under the common name of calciferous sandrock, as one formation.

[5] Op. cit., p. 23.

[6] Rogers, Henry D. Third Annual Report of the Geological Survey of the State of Pennsylvania. Harrisburg, 1839, pp. 14-16.

[7] Op. cit., p. 15.

In the fourth report[1] formation No. 1 is spoken of as the extensive slate and sandstone formation constituting "The lowest member of our older Secondary or Appalachian rocks." The slates of the Pigeon Hills are referred to the lowest Secondary formation of the State, and the strata comprise different portions of formation No. I, consisting of dark slate and a light colored sandstone. The stratigraphic succession of the various beds referred to formation No. I of South Mountain, southwest of the Susquehanna, is given in detail. The intercalated limestone bed is considered to belong to the upper part of the division,[2] and there is a bluish slate interstratified in the sandstone. In the report of the following year[3] the geographical range of the rocks of the South Mountains from the Delaware to the Schuylkill is outlined. The white and gray sandstone of formation I is not a continuous stratum in the belt of the South Mountains where they traverse Northampton and Lehigh Counties, but it is very probable it occurs at the base of all the primary ridges, buried under a deep covering of loose diluvium.[4] Mention is made of its various points of outcrop and its occurrence in Berks County, and many details are given of the distribution of the sandstone and the mode of its occurrence in relation to the subjacent primary rocks.

In his grand summary of the geology of Pennsylvania, Prof. H. D. Rogers gives a synoptic description of the Primal series or "Potsdam" sandstone of New York, as follows:[5]

The Primal series, under its fullest and most diversified condition, or that which it wears in the Appalachian chain in Pennsylvania, Virginia, and Tennessee, is a thick fourfold group composed of two slates and two great arenaceous rocks in alternation: (1) The highest or Primal newer slate is a greenish and brownish talco-argillaceous slate, sometimes very soft and shaly. In Pennsylvania it has a thickness of about 700 feet. (2) The next, the Primal white sandstone, is a compact, white and yellowish, fine-grained, vitreous sandstone, often containing specks of kaolin. This rock, which is of easy recognition and of an immense range, has a thickness in some parts of the Blue Ridge of Virginia of at least 300 feet. This is the Potsdam sandstone of New York. (3) The Primal older slate is a brown and greenish gray sandy slate, containing much feldspathic and talcose matter. It has hitherto disclosed no fossils. The thickness of this bed in the Atlantic slope in Pennsylvania is several hundred feet, and in the Blue Ridge of Virginia is not less than 1,200 feet. (4) The Primal conglomerate, the lowest of the yet distinctly recognized formations of the Primal series, is a heterogeneous conglomerate of quartzose, feldspathic, and slaty pebbles, imbedded in a talco-silicious cement. The thickness of this rock in Virginia and Tennessee, north of which it has not been discovered, is at least 150 feet.

In New York and the Northwestern States this series presents a materially different type, the Primal white sandstone being almost the sole representative.

Thickness.—The thickness of the entire series is considerably more than 2,000 feet.

---

[1] Rogers, H. D. Fourth Annual Report on the Geological Survey of the State of Pennsylvania. Harrisburg, 1840, pp. 33 35.

[2] Op. cit., p. 41.

[3] Rogers, H. D. Fifth Annual Report on the Geological Exploration of Pennsylvania. Harrisburg, 1841, pp. 16 26.

[4] Op. cit., pp. 26, 27.

[5] The Geology of Pennsylvania. Philadelphia, 1858, vol. 2, pp. 751, 752.

Geographical distribution.—In its geographical distribution this primal series ranges coextensively, or nearly so, with the other formations of the older Paleozoic division to be presently traced; that is to say, it shows two great continuous outcrops, one stretching southwest along the Appalachian chain and the other west from the St. Lawrence, through New York, Canada West, Northern Michigan, Wisconsin, and Minnesota beyond the Mississippi. It is probably likewise brought to the day in the anticlinals of Missouri, Arkansas and Texas, which elevate the gneissic strata on which it rests.

The only fossils found were a peculiar fucoid in the newer Primal slate, annelid borings in the Primal white sandstone, "one or two brachiopodus mollusks, especially lingula. In Wisconsin and other northwestern localities this formation contains several species of trilobites, and abounds in lingulæ, obolus, and an orbicula."[1] Trilobites were also found on Lake Champlain.

Under the heading of "Equivalents" is the following:

These strata seem to be on the horizon of the lower Festiniog group or lingula flags of England, and equivalent to the obolus and lingula sandstone of Sweden and Russia. They represent, too, the primordial zone of Bohemia, and are therefore on the horizon of the very dawn of discovered life.[2]

This summary of Prof. Rogers gives his information respecting the Primal series in Pennsylvania, Virginia, and Tennessee up to the time of publication. Under the heading of "Depositions and disturbances of the Primal period," he discusses the probable conditions under which the sediments were deposited, and sums up the period as one of vast duration; "an enormous age of quiet sedimentation with almost no life in the wide turbid sea."[3] The paleontological record for the Primal series is given a very few words: Three or four fossils known in the white sandstone, and a vaguely defined plant in the subjacent shale in the Appalachian region. But in Wisconsin, the white sandstone imbeds, on a succession of thin floors, some seventeen more species. Two of these are identical with those of the eastern outcrop, so the total number of species known at that date was eighteen. The distribution of the Primal series in Pennsylvania is tabulated in volume I[4] and local details are given in the description of the various counties in which outcrops of the rocks and slates occur.

On an accompanying geological map the geographic distribution of the Primal series is delineated. As a whole it extends with many interruptions diagonally across the southeastern portion of the State, from South Mountain in Adams County to Northampton and Bucks Counties, on the Delaware River.

Two maps of sections also accompany the report of 1858. On the line of section No. 2, the Primal is represented, in Northampton County, at Frey's Run and along Durham Creek to the Delaware River. At Attleborough, in Bucks County, a synclinal of the Primal sandstone is represented as occurring in the midst of the older Primal slate.

[1] Op. cit., p. 751. [2] Op. cit., p. 752. [3] Op. cit., p. 781. [4] Op. cit., pp. 122, 123.

Section No. 3 crosses the Primal slate in Berks County and represents the Primal sandstone dipping southeasterly from the Primal slate forming Mount Pleasant. The Primal sandstone is shown again in Montgomery County at Barren Hill and it is placed in the midst of "Primal mica slate."

Section No. 4, in crossing Lancaster and Chester Counties, passes through the Primal series at Neversink Hill, near Reading, and also at Welsh Mountain, where the Primal sandstone is represented as forming a low anticlinal.

On the line of section No. 5, the Primal sandstone occurs to the west of the Primal slates and gneiss that form Millbough Hill in Berks County. In Lancaster County, on the line of the same section, the sandstones occupy the south end of Welsh Mountain. In Mine ridge the Primal slates and gneiss are represented as much distorted, while the sandstone forms an anticlinal and synclinal axis.

Sections Nos. 7 and 8 cross the South Mountain in Adams and York Counties; and the entire section of the mountain is represented as Primal, as stated in the text. The rocks of Pigeon Hills, to the southeast in section 7, are also referred to the "Primal" and to the "Primal slate, altered and crystalline;" and the same reference is made of the southwestern extension of the slates of the hills where crossed by section 8.

I have been unable to find any account of original researches upon the Primal rocks during the period between the final report of Prof. H. D. Rogers and the renewal of their study by Prof. J. P. Lesley in 1873.

In a paper by the latter, on the iron ore of the South Mountain of Cumberland County, a diagrammatic sketch is given of a cross-section of the county at Carlisle, in which the "Potsdam" sandstone rests on the gneiss for a long distance.[1] On the following page a sketch of a section shows the sandstone, resting on the Azoic slates and gneiss; and beneath is a series of iron ore bearing slates that, in turn, are subjacent to the Calciferous sandstone and Trenton limestone.

In describing the Cornwall iron mines and some related deposits, in Pennsylvania, Dr. T. S. Hunt[2] refers Prof. Rogers's Primal slate of the mines to a portion of the Lower Taconic series of Emmons and beneath the horizon of the Potsdam sandstone of the New York system. This reference carries with it the ores which are found in Pennsylvania along the borders of the Mesozoic and Red Sandstone formations of this portion of the State.

In another paper Dr. Hunt notes the discovery by Prof. Prime of a species of Monocraterion, in the Auroral limestone of Pennsylvania, and says:

[1] The iron ores of the South Mountain along the line of the Harrisburg and Potomac Railway in Cumberland County, Pennsylvania. Am. Phil. Soc. Proc., vol. 13, 1873, p. 4.

[2] The Cornwall iron mine and some related deposits in Pennsylvania. Am. Inst. Mining Eng., Trans., vol. 4, 1876, p. 320.

These same limestones in Pennsylvania, which belong to the Lower Taconic series of Emmons, have also afforded an undescribed species of Lingula.[1]

In reporting on the Paleozoic rocks of Lehigh and Northampton Counties Mr. Fred. Prime, jr., states that the very lowest beds of the Potsdam sandstone are actually pudding-stones, containing pebbles the size of a man's fist and larger, and fragments of red, unaltered orthoclase. The upper beds are composed of a hard, compact quartzite containing greater or less quantities of feldspar nodules. The sandstone often, as elsewhere, contains Scolithus.[2] He gives the geographic distribution of the sandstone as found about the South Mountain in the two counties mentioned. Of the upper Primal slates he says:

Next above the Potsdam sand stone occur hydromica slates, which Rogers has called the Upper Primal slates, but which really form a portion of the No. II limestone, and gradually pass into this. They overlie the Potsdam conformably and are far more persistent in their occurrence.[3]

In the limestone he found specimens of the genus Monocraterion in Lehigh County, specimens of Lingula, and a single specimen of an orthoceratite.[4] In the vicinity of Allentown and Bethlehem the sandstone is about 25 feet thick. The contact between the gneiss and the sandstone is distinctly seen about 2 miles from Allentown, on the Lehigh Valley Railroad track. (Prof. Prime's paper was also printed in the American Journal of Science, under the following title: "On the Discovery of Lower Silurian Fossils in Limestone Associated with Hydromica Slates, and on other points in the Geology of Lehigh and Northampton counties, Eastern Pennsylvania.")[5]

The species of Monocraterion was described and illustrated by Prof. Prime in 1878.[6] It is stated to be from the Siluro-Cambrian limestone.

Prof. Rogers referred nearly all of the strata of the South Mountain, southwest of the Susquehanna River, to the Primal series. He says:

In its geological constitution this tract is without much variety, for it contain scarcely any rocks except those of the Primal series.[7]

He describes the ridges as composed of the Primal white sandstone and the intervening valleys and plateaus of the Primal upper slate. These strata are represented as very much disturbed and extensively metamorphosed. This view is not accepted by Dr. Persifor Frazer, who says that in his report of 1875 (Second Geological Survey of Pennsylvania, CC) it is clearly shown, both in the text and in the graphic illustrations, that the Potsdam or Primal formation of Rogers is wanting over all that country with the exception, perhaps, of scattered patches on the northwestern flank of the South Mountain chain.[8]

[1] On the history of the crystalline stratified rocks. Am. Assoc., Proc., vol. 25, 1876, p. 208.

[2] On the Paleozoic rocks of Lehigh and Northampton Counties, Pennsylvania. Am. Phil. Soc., Proc., vol. 17, 1878, pp. 248, 249.

[3] Op. cit., p. 249. [4] Op. cit., p. 251.

[5] Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 261–269.

[6] 2d Geol. Sur., Penn., DD, 1878, pp. 79–80.

[7] The Geology of Pennsylvania. Philadelphia, 1858, vol. 1, p. 203.

[8] Frazer, Persifor, jr. (On the relations of the South Mountain rocks in Pennsylvania.) Am. Inst. *Mining Eng.*, Trans., vol. 7, 1879, p. 336.

In noting the discovery of the Martic anticlinal in Lancaster County, Dr. Frazer calls attention to its exposing fundamental gneiss and granatoid beds in the new railroad cuttings along the left bank of the Susquehanna River and how it sheds off to the north and to the south at least 16,000 feet of Primal (Cambrian?) slates.[1] In a special report upon the geology of Lancaster County the same writer describes the character and mode of occurrence of the "Chikis" quartzite. The actual thickness of the quartzite above water level is not much over 300 feet.[2] Between the limestones and the quartzite there is, he says—

A vast series of hydro-mica schists and decomposed argillaceous slates, which insensibly grow in the deep more and more chloritic until this mineral lends its color as well as its name to the larger part of the whole formation, but generally the chloritic series is divided from these nacrites by a quartzite.[3]

He says further:

A vast series of slates intervene between the lowest rocks of all on the Susquehanna and the formation last described.[4]

As the result of his survey of the southern parts of Montgomery, Bucks, and Philadelphia Counties, Mr. Chas. E. Hall[5] decides that the South Valley Hill hydromica and chlorite slates, which were considered by Prof. Rogers as equivalent to his Primal of the North Valley Hill, are not altered Primal slates, but no other than a series of slates overlying the limestones of No. II or the slates of the Hudson Period. He also gives a description of the Primal quartzite of Rogers, speaking of it as the Potsdam sandstone.[6] He gives his opinion of the age of the sandstone known as the Edge Hill Rock, in Chester County, as follows: "The Itacolumite, or Edge Hill Rock, I consider proven, beyond dispute, to be the equivalent of the Potsdam sandstone."[7]

In a memoir upon the geology of the southeastern portion of Pennsylvania, Dr. Persifor Frazer gives a summary of the general characters and geographical distribution of the Primal quartzite and the subjacent and superjacent schists. The upper division of the Primal of Rogers is referred to No. III or Auroral, and the chloritic schists, subjacent to the quartzite, are referred to the Huronian, the quartzite alone representing the Primal or Potsdam of Rogers.[8] The geographic distribution of the formation in Chester, Lancaster, York, and Adams Counties is represented on the map accompanying the memoir.

Prof. Lesley, in his description of the geology of Chester County, after the surveys of Messrs. Rogers, Frazer, and Hall[9] writes:

---

[1] [Note on the Martic anticlinal and on ripple marks on a slab of limestone]. Am. Phil. Soc., Proc., vol. 17, 1878, p. 725.

[2] The geology of Lancaster County. Second Geol. Survey Penn., Rep. Prog. in 1877, CCC. Harrisburg. 1880, p. 7.

[3] Op. cit., p. 5. [4] Op. cit., p. 8.

[5] The geology of Philadelphia County and of the southern parts of Montgomery and Bucks. Second Geol. Survey Pa., C6., 1881, pp. xvii–xviii, 93.

[6] Op. cit., pp. 7, 8. [7] Op. cit., p. xvii.

[8] Mémoire sur la Géologie de la partie sud-est de la Pennsylvanie. Lille, 1882, p. 75.

[9] The geology of Chester County, after the surveys of Rogers, Frazer, and Hall. Second Geol. Sur. Penn., CCCC; 1883, p. viii.

Dr. Frazer divides the Potsdam sandstone formation into an upper and a lower. * * * The upper, or *Kennett rock* division, he identifies with Mr. Hall's Edge Hill rock.

The lower is the Toughkenamon division. Dr. Frazer himself says that the latter, or the lower division, "is composed of weathered particles of a gneiss or syenite loosely compacted and laminated." The second or Kennett rock is the upper division and "it is a thin-bedded rock, lying in plates of fairly parallel sides, composed of fragments of white limpid quartzite, and is generally large-grained."[1]

Prof. Lesley quotes Prof. Rogers's description of the Primal series as it occurs at various localities in the county, together with many of Dr. Frazer's observations; stating that he described three principal and a few very subordinate and doubtful areas of the Primal rock north of the Chester Valley. One important conclusion of Dr. Frazer's is here quoted:

In mentioning thus the "Primal," the quartzite and quartzose sandstone alone are considered here. It will be seen further on that abundant evidence sustains the view that the greater part if not all of the weathered feldspar porphyries, conglomerates, &c., in the townships both north and south of the Chester Valley are really *Lower Potsdam*. The effect of this would be to add a border of these rocks to the area of the (silicious) Potsdam as at present indicated on the map, and thus contract by this much the remaining area of real Azoic or Hypozoic.[2]

The report of Mr. E. V. D'Invilliers upon the geology of the South Mountain belt of Berks County contains an extended description of the "Potsdam" sandstone, or No. 1 of Rogers's classification. The opening paragraph throws a doubt upon the correlation that has been made of this lower sandstone with the Potsdam sandstone of New York:

It would be safer to name this formation the *Reading Sandstone;* but in the descriptions of its outcrops along the Little Lehigh, the Lehigh, and the Delaware Rivers, in vol. I of this report, it has been called *Potsdam Sandstone*, taking for granted that any sand formation underneath the Magnesian limestones of the Great Valley must be the same sand formation which in northern New York underlies the Corniferous [Calciferous?], Chazy, and other limestones of the Mohawk Valley.[3]

The lower sandstone or conglomerate and the lower Primal slates of Rogers were not recognized in Berks County.

The lowest bed of the sandstone, always seen resting on the gneiss, is a coarse conglomerate of angular quartz rock fragments of all sizes in a silicous paste. * * * The term *sub-Potsdam conglomerate* would express its position underneath the *Potsdam quartzite white sandstone proper*, belonging to it by conformity, and separated from the gneiss by nonconformity.[4]

A detailed description of the outcrop of the sandstones and their general character follows. Certain areas of slate exist in places between the sandstone and the Magnesian limestone and are referred to the Primal series. Where the slate is not present the limestone is im-

[1] Geological notes in the several townships of Chester County. Second Geol. Surv. Penn. The geology of Chester County. C4, 1863, p. 307.

[2] The geology of Chester County, after the surveys of Rogers, Frazer, and Hall. Second Geol. Surv. Penn., CCCC; 1883, p. 159.

[3] The geology of the South Mountain Belt of Berks County. Second Geol. Surv. of Penn., D3, 1883, vol. 2, p. 99.

[4] *Op. cit.*, p. 100.

mediately above the Potsdam sandstone. "Its place in the series is next above the Potsdam sandstone formation No. I."[1]

In a lecture upon the geology of Philadelphia, Prof. H. Carvill Lewis describes the Primal slates and Potsdam sandstone as follows:

On top of the gneiss and at the base of that great group of fossiliferous rocks known as the Paleozoic System, is a peculiar formation in the middle strata of which occur the oldest fossils yet found in the vicinity of Philadelphia. The lower part of the formation is the pale sandy slate which forms Edge Hill and Barren Hill, and the northern base of Chestnut Hill. The slates are closely folded and stand often almost perpendicular. * * * A sandstone, which from its great development at Potsdam, N. Y., has been named from that place, overlies the slates and often contains long tubular fossils, known as *Scolithus linearis*, which appear to be the casts of worm-holes. * * * On top of this fossiliferous sandstone is a series of soft, iron-bearing shales, often decomposed into variegated clays, carrying extensive beds of iron ore (limonite).[2]

The "Potsdam" sandstone is described by Prof. Fred. Prime, jr., as it occurs in Lehigh and Northampton Counties. It rarely exceeds 25 feet in thickness, and there are no underlying rocks of any thickness between it and the unconformably subjacent Laurentian rocks. The Primal upper slate of Rogers is classed with the Siluro-Cambrian limestone.[3]

Prof. J. P. Lesley's hand atlas of the sixty-seven counties of Pennsylvania contains a description of the rocks referred to the Potsdam quartzite, No. I, of Rogers, in each of the counties in which they occur; and the geographic distribution is shown upon the maps of the counties. The text presents the best general statement of the distribution of the strata now referred to the Cambrian in Pennsylvania that has yet been published.[4]

Prof. Lesley's résumé was followed in 1886 by an important contribution by Dr. Persifor Frazer entitled "A sketch of the Geology of York County, Pennsylvania." In adopting the classification of the Geological Congress for the system he places under the heading "Cambric" the Hellam quartzite or Potsdam sandstone.[5] The lower series or talcose slates of Rogers are considered in all probability as identical with the Azoic schists; and it is stated that abundant instances occur of the unconformable contact of the quartzite upon the supposed equivalent schists in Chester County. On the geological map accompanying this memoir the details and distribution of the Potsdam formation are delineated. The talcose schist of Rogers, or the upper member of his Primal series, is referred to the "Siluric" as "hydro-mica schists."[6]

Dr. T. Sterry Hunt objects to the interpretation of Prof. Rogers, that

---

[1] Op. cit., p. 137.

[2] The geology of Philadelphia. Franklin Inst. Jour., 3d ser., vol. 85, 1883, p. 425.

[3] Geology of Lehigh and Northampton Counties. Second Geol. Surv. Penn., D3, vol. 1, 1883, pp. 210, 212.

[4] A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the Verity field work of the survey, from 1874 to 1884. Second Geol. Surv. Penn., X, 1885, pp. cxii.

[5] General notes. Sketch on the geology of York County, Pennsylvania. Am. Phil. Soc., Proc., vol. 23, 1886, p. 398.

[6] Op. cit., p. 400.

the Primal sandstone, Auroral limestone, and Matinal shales of central Pennsylvania are represented in southeastern Pennsylvania. He criticises the correlation upon the evidence of the presence of *Scolithus linearis*, stating that he has shown it to be very distinct from that found in the Potsdam sandstone. The argument for this is given in his "Azoic Rocks of Pennsylvania."[1] In a later publication Dr. Hunt concludes that—

> There is, in fact, up to this time, no evidence that the typical Potsdam sandstone and Calciferous sandrock of northern New York exist in eastern Pennsylvania; but on the contrary there are many reasons for supposing that in this region, as in eastern Canada and along the eastern side of the Champlain and Hudson River Valleys, the period of these two subdivisions of the New York system is represented by the First Graywacke of Eaton, the Upper Taconic of Emmons, which, as will be shown farther on, is now recognized as contemporaneous with the typical Potsdam and Calciferous subdivisions. Rocks supposed to represent this Graywacke series are found in the great valley of Pennsylvania, and these, together with the divisions immediately preceding them—namely, the Primitive quartz rock, the Primitive lime rock, and the transition argillite—which constitute the Lower Taconic of Emmons—are, as we shall endeavor to show, represented by the so-called Primal, Auroral, and Matinal of the southeastern area.[2]

He refers the sandstone, limestone, and shale to his pre-Cambrian Taconian system, correlating the formations with the Granular quartzite, Granular limestone, and Transition argillite of the eastern New York section. This correlation, made long before by Prof. Rogers, is sustained by the latest observations. The "Granular quartz" of Eaton's section is known to be of Lower Cambrian age; the limestone, of the Trenton-Chazy horizon, and the argillite is referred to the Hudson terrane. If the correlation based upon lithologic characters and stratigraphic position by Messrs. Rogers and Hunt be correct, then the quartzite of southeastern Pennsylvania is of Cambrian age, and the limestones, with their superjacent shales and schists, are the equivalents of the Trenton and Hudson terranes.

The statement that the Upper Taconic of Emmons is contemporaneous with the typical Potsdam and Calciferous subdivisions is no longer sustained, as the Upper Taconic of Emmons is mainly the Lower Cambrian of the New York section.

In a discussion on the rocks of Pennsylvania and New York, Mr. T. D. Rand[3] mentions the Cambrian of Chester Valley, near Philadelphia, and, as undetermined, the hydro-mica schist of the South Valley Hill. He states that the Potsdam really exists in between the schist and the limestone, which refers the schist to the Archean. The sandstone is very thin, but it rests upon the Laurentian shore of the ancient ocean, which explains the differences of thickness as compared with the rocks to the northwest.

[1] Special report on the trap dikes and Azoic rocks of southeastern Pennsylvania. Second Geol. Surv. Pa., E. 1878, pp. 134–139.

[2] The Taconic Question in Geology. Mineral Physiology and Physiography. A second series of chemical and geological essays: 1886, p. 534.

[3] A discussion on the rocks of Pennsylvania and New York. New York Acad. Sci., Trans., vol. 8, 1889, pp. 50, 51.

MARYLAND.

A brief description is given by Prof. P. T. Tyson, in his first report,[1] of the rocks in Maryland referred to the Primal series of Rogers. Two formations are referred to the Primal: (1) a hard sandstone; and (2) a slate, varying in color from gray to brownish and greenish. On the map accompanying the report the geographic distribution of the Primal series is indicated.

VIRGINIA.

One of the earliest attempts to differentiate, by lithologic characters, the formations of the Blue Ridge of Virginia is on the map of a section crossing it east of Winchester.[2] The Transition, or blue limestone, is represented as passing beneath the limestone shale that, in turn, dips beneath a gray schistose rock. This section is of interest only when interpreted by the later sections of Prof. Rogers.

Prof. William B. Rogers describes in the Second Report of the Progress of the Geological Survey of Virginia the Primal series in the central counties of the State, or of the Great Valley, as follows:

(No. 1.) This rock or group of rocks, which is frequently exhibited in extensive exposures along the western side and base of the Blue Ridge, more especially in the middle counties of the valley, is usually a compact, rather fine-grained, white or yellowish gray sandstone. Where resting on the declivity of the ridge it presents a gentle inclination to the northwest—while the subjacent and more ancient strata of the ridge, in almost every instance, dip steeply to the southeast. In Page, Rockingham, Augusta, and Rockbridge counties this rock forms the irregular and broken ranges of hills lying immediately at the foot of the main Blue Ridge, and sometimes attaining an altitude little inferior to that of the principal mountain. A level region, sometimes of considerable breadth, and strewed profusely with the fragments of this rock, in general intervenes between these rugged hills and the first exposures of the valley limestone. * * * Talcose and micaceous matter make their appearance in it. * * * This micaceous and talcose variety is sometimes found in the same hill underlying the more purely silicious rock. The latter, in nearly all the exposures from the Balcony Falls to Thornton's Gap, as well as in various other places, exhibits vague, fucoidal and zoophytic impressions on the surfaces of bedding, together with innumerable markings at right angles to the stratification, penetrating in straight lines to great depths in the rock, and from their frequency and parallelism determining its cleavage in nearly vertical planes. These markings are of a flattened, cylindrical form, from one-eighth to one-tenth of an inch broad, giving the surface of the fractured rock a ribbed appearance, and resembling perforations made in sand which have been subsequently filled up without destroying the distinctness of the original impression. Precisely similar markings are found in great abundance in the white compact sandstone occurring at a higher point in the series, associated with numerous unequivocal impressions of fucoides.

The extent to which these sandstones are developed is comparatively inconsiderable in the southern and northern counties of the valley, and their structure and composition are in many respects materially changed.[3]

---

[1] First Report of the State Agricultural Chemist of Maryland. Annapolis, 1860, pp. 34, 35.

[2] Clemson, Thos. G.: Notice of a geological examination of the country between Fredericksburgh and Winchester, in Virginia, including the gold region. Geol. Soc. Penn., Trans., vol. 1, 1835, map, oppo. p. 298.

[3] Second report of the progress of the geological survey of the State of Virginia, for the year 1837. Richmond, 1838, p. 14.

The description of formation No. I in the third annual report is as follows:

The lowest of the Appalachian rocks consist for the most part of a close-grained white or light gray sandstone, in some places containing beds of a rather coarse conglomerate of white silicious pebbles. Near the bottom in many instances a brownish slaty sandstone occurs alternating with the former, while towards the top or approaching the next formation, the sandstone passes into reddish and brownish and olive-colored argillaceous slates.

This formation in Virginia is exclusively confined to the western slope of the Blue Ridge and the narrow belt of rugged hills and mountains extending thence to the commencement of the valley limestone.[1]

In a paper on "The Lower Silurian brown hematite beds of America," Mr. B. S. Lyman states that all these beds seem to lie within the Virginia and Pennsylvania geological formation No. I, wholly below the Calciferous Sandrock of No. II.[2]

On the map accompanying the reprint of the annual reports and other papers on the geology of the Virginias, published in 1884, Prof. Rogers has included under one color, formations I to III or the Primal, Auroral and Matinal series. On the large series of sections, however, the three are differentiated and No. I or the Primal series is shown in sections 1 to 19, and also in 89.

Prof. W. M. Fontaine has added many details to the section of the Primal series described by Prof. Rogers, at Balcony Falls in Rockbridge County. The sketch of the Balcony Falls section[3] is supplemented by that of Rockfish Gap and Harper's Ferry.

For a further notice of the results of Prof. Fontaine's work the reader is referred to the description of the Cambrian rocks of Virginia.

In a note upon the Potsdam or Primal group of Virginia, prepared for Macfarlane's American Geological Railway Guide, Prof. W. B. Rogers puts as equivalent formations No. I of the Pennsylvania and Virginia surveys or Primal of the annual reports and Potsdam group. The latter is used in the nomenclature of the rocks of Virginia and West Virginia. In the note explaining the Potsdam group, he says:

The Potsdam, or Primal group, includes in Virginia, where complete, besides the Potsdam proper, the ferriferous shales next above, and the slates, shaly grits, and conglomerates, below this formation. It is exposed in varying mass and completeness on the western slope and in the west flanking hills of the Blue Ridge throughout much of its length, often, by inversion, dipping to the southeast, in seeming conformity beneath the older rocks of the Blue Ridge, but often, also resting unconformably upon or against them. These older rocks, comprising masses referable probably to Huronian and Laurentian age, include also a group of highly altered beds, corresponding apparently to the copper-bearing or Keweenian series of northern Michigan, and perhaps to the lately described Dimetian rocks of Wales.[4]

[1] Report of the progress of the geological survey of Virginia, for 1838 (Richmond, 1839), p. 6. A reprint of the annual reports and other papers, on the geology of the Virginias. New York, 1884, pp. 197, 198.

[2] On the Lower Silurian brown hematite beds of America. Am. Assoc., Proc., vol. 16, 1867, p. 114.

[3] On the primordial strata of Virginia. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 363-369.

[4] *Rogers*, W. B. Virginia and West Virginia. [Geological formations.] Macfarlane's Am. Geol. R. R. Guide, 1879, p. 181.

It will be noticed that Prof. Rogers adopts the same reference for the ferriferous or iron-bearing slates and shales that his brother did for the supposed equivalent formation in Pennsylvania.

Prof. J. L. Campbell published two papers in 1879,[1] in which the Primal series of Prof. Rogers is described. These were followed in 1880 by a revised description of the Silurian formation in central Virginia.[2] His observations will be noticed in the section on the Cambrian rocks of Virginia. In another paper he gives a definition of the "*Primordial*" as follows:

The Primordial.—The great bed of ferriferous shales and sandstones skirting the western base of the Blue Ridge from Tennessee to the Potomac; in the upper part of formation No. I of Prof. Rogers's Appalachian series.[3]

The most complete and detailed description of the formations referred to the Primal series of Rogers is that of Prof. W. M. Fontaine, published in 1883.[4] The section is formed of conglomerate at the base, subjacent to shales, upon which the so-called Potsdam quartzite rests. The upper member of the Primal series is the ferriferous shales. The entire thickness of this section is given as 2,380 feet, and the data given by Prof. Fontaine will be used largely in the summing up of our knowledge of the Primal series in Virginia. The reader is referred to that section for further details.

In an article upon the iron ores of the valley of Virginia, Mr. Andrew McCreath divides the "Primal or Potsdam sandstone" (Primal or Potsdam formation) into (1) lower slates, (2) sandstone, (3) upper slate.

First. In the *lower slates*, or those geologically underneath the Potsdam sandstone occurs a red hemitite ore, sometimes in beds of considerable thickness and of good quality. This is the so-called "specular ore" of the Blue Ridge, and it has been quite extensively developed at numerous points, notably in Botêtourt and Bedford Counties. * * * Second. In the *Potsdam sandstone* itself, important beds of iron-ore have been observed. The ore is generally a close-grained, brittle, dark brown hematite, invariably cold-short. In Rockbridge County a bed of it fully ten feet thick is exposed for a considerable distance on the Vesuvius property. * * * Third. The *upper slates*, however, are by far the most important from an economical standpoint, forming, as they do, one of the richest repositories of brown hematite iron ore in Virginia. They intervene between the Potsdam sandstone and the base of the calciferous limestone, and they are found all along the western slope of the Blue Ridge—being geologically coextensive with it. They are generally more or less disintegrated, or decomposed into variegated clays; and while they may not always carry a continuous ore bed, yet, wherever the formation exists, deposits of iron ore of greater or less extent may be confidently looked for.[5]

---

[1] Silurian formation in central Virginia. Am. Jour. Sci., 3d ser., vol. 18, 1879, pp. 16–29. Geology of Virginia; Balcony Falls; The Blue Ridge and its geological connections. Some theoretical considerations. Ibid., pp. 435–445.

[2] The Silurian formation in central Virginia (revised). The Virginias, vol. 1, 1880, pp. 41–45, 54–56.

[3] The mineral resources and advantages of the country adjacent to the James river and Kanawha Canal and the Buchanan and Clifton Forge Railway. The Virginias, vol. 1, 1880, p. 3.

[4] Notes on the mineral deposits at certain localities on the western part of the Blue Ridge. The Virginias, vol. 4, 1883, pp. 21, 22, 42–44.

[5] The iron ores of the valley of Virginia. Am. Inst. Mining, Eng., Trans., vol. 12, 1884, pp. 18–20.

In the sheet of sections accompanying "The Virginias" by Prof. William B. Rogers, printed in 1884, section 9 crosses the Primal series of Rockbridge County, about 30 miles north of Balcony Falls. On the eastern slope of the Blue Ridge a small synclinal basin of the Primal series is represented as resting in a hollow in the gneiss; on the western slope, the Primary series is shown as it occurs in numerous sections crossing the Great Valley and the Blue Ridge. The editor of the sections, Mr. Jed. Hotchkiss, states in the note accompanying them that the sections are "exact reproductions, in so far as the geology is concerned, of the sections as Prof. Rogers left them." From this it is evident that Prof. Rogers became aware of the presence of the Primal series on the upper eastern slope of the Blue Ridge in Rockbridge County after the publication of the third annual report in 1839, as he stated then that the Primal rocks were confined to the western side of the ridge.

Messrs. J. L. and H. D. Campbell, while studying the geological relations of the Snowdon slate quarries in Amherst County, on the borders of the counties of Rockbridge and Bedford, discovered the presence of the Balcony Falls series of Cambrian rocks and found that the quartzite passed beneath the slate of the quarries.[1] On the map accompanying the paper (p. 170), an ideal section shows the shales and conglomerates resting on the gneiss beneath the sandstone, which they have referred to the Potsdam owing to its carrying Scolithus borings, and above the latter is the slate belt, in which the quarries are located. Under the title of "Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view," Prof. Campbell corrects the statement made in a former paper, in the American Journal of Science in 1879, that the rocks of the southeast slope are of Archean age. He adds a sentence as follows:

> We may conclude, therefore, that this portion of the Blue Ridge has been formerly spanned by a grand arch, or series of arches, of Cambrian age, upturned perhaps at the time of their upheaval—the broken fragments of which have been carried away, and only the abutments left to tell the story of a great catastrophe.[2]

In a letter on relation of Archean and associated formations in Virginia, Prof. W. M. Fontaine states that he finds in Virginia a valuable guide to the true base of the Potsdam in the conglomerates.

> The lowest conglomerate is not always seen. It is often very coarse, with pebbles sometimes 4 to 5 inches in diameter, and composed of Laurentian or Huronian material, according to the nature of the underlying rock. The matrix is often shaly or slaty.
>
> It is the conglomerates overlying this stratum that afford the best guide, for they may always be seen.
>
> They are simply pebble beds in the slate or shale. The pebbles are from the size of a musket bullet down, and usually of quartz, often pink in color. The pebbles look as if they had been scattered over a muddy bottom, forming a very peculiar conglomerate in which all the material except the pebbles is a fine slate or shale. Sometimes some partially decayed feldspathic matter occurs with the pebbles.

[1] The Snowdon slate quarries. The Virginias, vol. 5, 1884, pp. 162, 163.

[2] *Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view.* Am. Jour. Sci., 3d ser., 1884, vol. 28, pp. 222, 223.

These *shaly conglomerates*, as we may call them, might sometimes be *mistaken for certain amygdaloids of the Huronian* when the latter are weathered, but careful examination will always detect the difference. I have never seen any shaly conglomerate in the Huronian.

I am now of the opinion that the conglomerates at the railroad bridge at Harper's Ferry are these lower Potsdam strata, but would require a reexamination of them before I make up my mind positively. I am also inclined to think that Frazer's Mountain Creek conglomerate is the same.[1]

During the year 1885 Prof. H. D. Campbell published a more detailed account of the discovery of the Potsdam group east of the Blue Ridge. A résumé of the section is given as it occurs on the northwestern slope of the Blue Ridge at Balcony Falls for the purpose of comparing the rocks as found upon the southeastern slope. On the eastern slope the strata lie in a basin of Archean rocks forming a synclinal, a section of which practically reduplicates the lower portion of a section of the "Potsdam group" of the western slope. A map and figure of the section accompany the paper.[2] In a second article in connection with his father, the Cambrian-Primordial (No. 1 of Rogers) is described in considerable detail,[3] and mention is made of the discovery of another area referred to the "Potsdam group" on the eastern slope of the Blue Ridge, at Tye River gap, in Nelson County.

Prof. J. J. Stevenson identifies the Cambrian rocks, crossing Montgomery, Pulaski, and Wythe Counties, as the Lower Knox shales and the Potsdam of the Tennessee section. Under the title "Cambrian" he says:

> Here are placed the Lower Knox shales and the Potsdam. The former are probably equivalent to the Hydromica schists of Pennsylvania and the lower part of the Calciferous of New York; the latter is the Potsdam of New York, vastly increased in thickness.

No fossils were observed in the Knox or the Potsdam shale with the exception of *Scolithus linearis*. The geographic distribution of the formations referred to the Cambrian is shown on a map accompanying the paper. Further reference will be made to Prof. Stevenson's paper in describing the Cambrian rocks of Virginia.[4]

In a paper read before the Geological Society of America December 31, 1890, by Messrs. H. R. Geiger and Arthur Keith, it is stated that the shales and quartzite at Harper's Ferry represent the Hudson and Medina series and not the Primal series as stated by Profs. Rogers and Fontaine. They present a number of sections showing the stratigraphic position of the beds. In these the normal succession is limestone, shales, and sandstone. The shales succeed the limestones, and overlap

---

[1] (Letter on relations of Archean and associated formations in Virginia.) Geol. Chester Co., Pa., 2d Geol. Surv., C4, 1883, p. xv.

[2] The Potsdam group east of the Blue Ridge at Balcony Falls, Virginia. Am Jour. Sci., 3d ser., vol. 29, 1885, pp. 470–474.

[3] Review of William B. Rogers's Geology of the Virginias. Am. Jour. Sci., 3d ser., vol. 30, 1885, pp. 364–368.

[4] A geological reconnaissance of Bland, Giles, Wythe, and portions of Pulaski and Montgomery Counties of Virginia. Am. Phil. Soc. Proc., vol. 24, 1887, pp. 86–87.

upon the pre-Paleozoic rocks, the quartzite in turn resting upon the shales. This makes the limestones represent the Great Valley limestone of Virginia or the Calciferous-Chazy-Trenton belt; the shales, the Hudson series, and the sandstone, the Medina series of the New York section.[1]

NORTH CAROLINA.

As now known the Cambrian rocks of North Carolina are confined to the extreme western boundary, where the Ocoee conglomerate and Chilhowee sandstone series extend across from Tennessee. This was recognized by Prof. J. M. Safford in his work in Tennessee; and Prof. W. C. Kerr notes the occurrence of thin-bedded, siliceous slates at Paint Rock, on the State line. He says of them:

> They are called by Prof. Safford, the geologist of the State of Tennessee, Chilhowee sandstones, and are set down conjecturally by several eminent geologists as Potsdam sandstone. They have never yielded any fossils by which their geological horizon might be determined. A few very thin beds of argillaceous slate are found interpolated here and there between the quartzose strata.
>
> Passing up the deep gorge which the river has excavated, the quartzites are soon found to be interbedded with and are finally replaced by shales and grits, the latter generally fine, but occasionally approaching in appearance a breccia or conglomerate. These are succeeded by heavy beds of argillaceous slates and shales, which in turn give place, at Warm Springs, to a heavy bedded blue and gray limestone. This is followed by a calcareous, compact, fine-grained sandstone, which presently passes into a gray, much jointed quartzite rising in vertical cliffs along the river for 2 miles, and succeeded by a well characterized coarse conglomerate with bluish gray slates and shales, at and below the mouth of Laurel River. A little above this point comes in a very extensive and conspicuous bed of feldspathic quartzite, or petrosilex, which continues for more than a mile, and then graduates through a gneissoid rock into a series of gray, drab, and mottled argillaceous slates and shales. This succession of quartzites, grits, shale, limestone, and conglomerate occupies in direct cross section a space of more than 10 miles. I have elsewhere referred to the identity of this formation with that which is so conspicuous on Valley River, and shall therefore call it the *Cherokee Slates*. They pass in a northeast course up the Laurel Valley and through the Smoky or Unaka Mountains into Tennessee.[2]

In a note on the occurrence of metamorphic Silurian rocks in North Carolina, Prof. F. H. Bradley states that the rocks about Franklin are of Lower Silurian age, and the marbles of Murphy and vicinity are the equivalents of the Knox limestones of Tennessee, which are of Quebec group age.[3] This statement of Prof. Bradley's is noted here, as it is probable that the formations examined by him are equivalent to those exposed on the French Broad, between Warm Springs, North Carolina, and Paint Rock. If so, they may be of Cambrian age. In a paper published the following year, Prof. Bradley refers[4] to the strata in the vicinity of Murphy, in southwestern North Carolina, and takes the view

[1] Bull. Geol. Soc. America, vol. 2, 1891, pp. 155-163.

[2] Report of the State Geologist of North Carolina. Raleigh, 1869, p. 29.

[3] Note on the occurrence of metamorphic Silurian rocks in North Carolina. Am. Jour. Sci., 3d ser., vol. 8, 1874, p. 390.

[4] On the Silurian age of the southern Appalachians. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 286, 382.

already mentioned. There is, however, more or less of uncertainty in relation to the identification of the rocks about Murphy and on the line of the Hiwassee River; so much so that outside of the recognized Chilhowee strata I think it would be very hazardous to state that the Cambrian is represented in southwestern North Carolina. In his description of the stratified rocks, Prof. Kerr states that so far as known the Primordial is represented only in its lowest member, where it crosses the northwest border in a few points along the Smoky Mountain.[1] A description of the section upon the French Broad, from Paint Rock to Warm Springs, is reprinted by him (pp. 138, 139), with the statement that Prof. Safford makes the Paint Rock sandstones to be Chilhowee or Potsdam; the grits and conglomerates below and above Warm Springs to be Ocoee or sub-Potsdam; while the limestone is referred to the Knox Dolomite, which is above the Potsdam.[2] He also gives Prof. Bradley's identification of the rocks that belong to Cherokee County in the southwestern portion of the State.

TENNESSEE.

The classification adopted by Dr. Gerard Troost, in his fourth report as geologist of the State of Tennessee, is as follows:[3]

1. Primordial, or Primitive, or Crystalline.
2. Transition or Fragmentary.
3. Secondary or Sedimentary.
4. Tertiary or Upper Secondary.

In mentioning this classification he says:

> I should have confined myself to the two first parts of this division, the Primordial and Transition series, as they constitute the greatest part of the district that I have examined.

This nomenclature is used in the fifth annual report, where he states that the Crystalline Primordial rocks form the highest part of the Appalachian Chain. The line of contact of the Primordial rocks with the Transition or Fragmentary coincides in a general way, but not exactly with the boundary line between Tennessee and North Carolina.

> The country lying between the Great Smoky Mountains and the Cumberland Mountains, or East Tennessee, is for the most part composed of strata of grauwacke, sandstone, and limestone alternating with each other, and in which organic remains are rarely found; these strata are highly inclined, approaching in some places towards the vertical, dipping more or less towards southeast and running nearly parallel with the Smoky Mountain ridge; they are covered in several places by horizontal strata of limestone of a dark gray, approaching to a black color, and having a granular structure. It is in some places characterized by *Maclurites*, Le Sueur, *Conotubularia*, nobis, *Isotellus*, Dekay, and several species of *Calamopora*, Goldf.[4]

On the map and sections accompanying the report the Primordial or Crystalline series is colored blue, and the Secondary or Grauwacke

[1] Report of the geological survey of North Carolina, vol. 1, 1875, p. 115. Raleigh.
[2] Op. cit., p. 140.
[3] Fourth report of the geologist of the State of Tennessee. Nashville, 1838, p. 338.
[4] Fifth geological report on the State of Tennessee. Nashville, 1840, p. 5.

series, composed of grauwacke, slaty grauwacke, sandstone, and limestone, which extend from the Primordial series to where they are lost under the Cumberland Mountains, is colored yellow, thus roughly outlining the relations of the Cambrian and pre-Cambrian rocks of eastern Tennessee.

Before publishing the Sixth Annual Report, Dr. Troost read Murchison's "Silutia," and also the observations of Prof. Sedgwick on the Cambrian rocks of Wales. In discussing the changes of nomenclature made necessary in accepting the views of Messrs. Murchison and Sedgwick, he says:

After having pointed out, in my last report, the line of junction of the Primordial or crystalline rocks in East Tennessee, I mentioned that the country west of the line, which separates Tennessee from the State of North Carolina, is composed of grauwacke, slate, limestone, etc. All this country, according to the views of Murchison and Sedgwick, belongs to a new division, which they call the *Cambrian system*.

This series of strata contains few organic remains; in fact, I have carefully examined, in this respect, the Tennessee strata and have never discovered any in them.[1]

In his attempt to identify the Cambrian and Siluriansy stems in Tennessee, he included rocks in the Cambrian system that, under the original definition of Sedgwick for that system in Wales, is surprisingly correct. In describing the geographic distribution of the Cambrian system, he says:

I consider the termination of the *Cambrian System* towards the west. This system commences, as already observed, about the line which separates the State of Tennessee from North Carolina; and, as mentioned in my preceding reports, is also, with a few exceptions, the line of separation between the transition and primordial strata. It runs sometimes a few miles into North Carolina; sometimes penetrates, for a few miles, into Tennessee, forming the great Unica or Smoky Mountain, Bald Mountain, and Iron Mountains; but the culminating ridge of this mountain chain is mostly composed of the Cambrian rocks, while south of it the crystalline or Primordial rocks are found.

Leaving this ridge in a north, or rather northwest direction, we have a series of slaty rocks, containing here and there chlorite, passing into talcose slate—or into quartzite. This series seems to be equivalent to Sedgwick's *Lower Cambrian* series; some extensive strata, mostly of brown or reddish brown, fine grained limestone occur occasionally in this series; such a stratum is seen about 5 miles west from the Primordial rocks, crossing, near the Warm Springs in Buncombe County, the French Broad River. We have then a series of strata of slates and sandstone, and about 4 or 5 miles west of Newport a limestone stratum appears again, extending through Cocke and Sevier counties, parallel to the above-mentioned high chain. I suppose the Lower *Cambrian system* terminates there.

Upon the Lower Cambrian rocks follows another series. It is composed of roofing slate, glossy aluminous slate, and sandstone. A ridge of fine roofing slate crosses Sevier County. I believe that this series commences with Star's, Tellico, and Chilhowee Mountains in McMinn, Monroe, and Blount counties, ranging parallel with the great Smoky Mountain, extending in a southeastern direction through Sevier County. I have not been able to trace it further to the northeast. This series seems to be equivalent to the Middle Cambrian. * * *

I consider, as stated above, that Bay's Mountain forms the upper part of the *Cambrian system*—or, that it perhaps belongs to the Old Red sandstone—that hence towards

[1] *Sixth* annual report of the geological survey of Tennessee, by the State geologist. Nashville, 841, p. 4.

the north of that mountain chain another formation commences, which is the *Silurian system* of Murchison, and extends northward as far as the line which separates this State from Virginia—in fact, it continues into that State.[1]

In his description of Sevier County the roofing slate and other slaty rocks and the non-fossiliferous limestones are referred to the Cambrian group.[2]

Dr. Troost identified the Cambrian group in Tennessee with that of Wales entirely upon the lithologic characters and the absence of organic remains; and upon the fact that it was succeeded by a series of limestones from which he obtained and identified Silurian fossils. Although, in the light of our present knowledge, there were many inaccuracies in this correlation it exhibits a comprehensive grasp of the views expressed by Messrs. Murchison and Sedgwick and unusual clearness in the correlation of the groups of rocks in the two countries.

In a sketch of the general geology of the Hiwassee copper region Prof. J. P. Lesley describes the primary region of the Hiwassee and Ocoee Rivers as a southern prolongation of the metamorphic rocks of the Blue Ridge, South Mountain, and Highlands of the Middle and Northern States.

> It greatly resembles in every important geological particular the range of the White Hills in New Hampshire. * * * * They are not primary rocks, granites or porphyry, but the Primal and Matinal sandstones, shales, and limestones and conglomerates at the base of the older secondary series, baked, crystallized and upturned in collapsed synclinal and anticlinal axes.

He describes the section on the line of the Ocoee River as formed of slightly metamorphosed conglomerate strata.

> In places these rocks are a simple pea conglomerate, quartzose, and interstratified with the hardest homogeneous blue and gray grits and scarcely altered.[3]

The preceding correlation was based upon the view that the strata now referred to the pre-Cambrian Algonkian series were metamorphosed Primal and Matinal rocks, corresponding in age to the unaltered Primal and Matinal rocks to the westward. That they might form a great group of strata beneath the Primal and superjacent to the Primary proper, or Archean, was not at the time entertained by the writer.

In 1856 Prof. J. M. Safford published his first report of "A Geological Reconnaissance of the State of Tennessee," in which he classified the formations as follows:[4]

Formation I.—The mica slate group.
II.—The Ocoee conglomerates and slates.
III.—The Chilhowee sandstones and shales.
IV.—The Magnesian limestone and shale group.

---

[1] Op. cit., pp. 5, 6. [2] Op. cit., p. 28.

[3] First annual report of the board of directors of the Hiwassee Mining Company, made May 11, 1853. New York, 1853, p. 16.

[4] A Geological Reconnaissance of Tennessee; first biennial report. Nashville, 1856, pp. 151–154.

Formations III and IV were referred to the Cambrian system, and the formations above IV to the Silurian and Devonian systems, etc.

The term Cambrian was used provisionally to unite the first two fossil-bearing formations. The upper portion of formation No. IV, or the limestone member, was subsequently, in 1869, referred to the Knox dolomite.

This preliminary report was followed in 1869 by the volume on "Geology of Tennessee," in which all the strata now referred to the Cambrian are described in detail.[1] A map illustrating the geographic distribution of the formations in the State, and a transverse section from the North Carolina line west, showing the stratigraphic relations of the formations, accompanies the volume.

In speaking of the age of the metamorphic rocks of eastern Tennessee, which have been referred to by various authors as altered Silurian rocks, Prof. Safford says:

> I have no reason for believing that this group within Tennessee includes the metamorphosed beds of any formation of more recent date than the Ocoee conglomerate and slates. A portion of the beds are certainly referable to the Ocoee group; the remainder, although conformable, may be older, and most likely are. * * * In the northern part of the State, at many points, the passage of the Ocoee beds into gneiss is gradual and apparent. A considerable part, indeed, of our metamorphic rocks can be, I think, thus referred to these beds. The question as to the greater age of other parts is not so easily settled, and must remain open for the present. I know of no sufficient reason for referring any of these rocks to the Huronian or Laurentian series of Canada.[2]

It will thus be seen that the line of demarcation between the pre-Cambrian rocks and the Cambrian rocks has not been closely defined in Tennessee. It is only by comparison with the more clearly defined line found in the sections of the Blue Ridge in Virginia that we are led to consider that the metamorphosed rocks belong to an Algonkian group between the Cambrian and the Archean. The studies which are now in progress under the direction of the Geological Survey clearly demonstrate this, and give as the base of the Cambrian a series of sandstones. Where the sandstones and conglomerates are made up of the material derived from the adjacent Algonkian or Archean rocks they will necessarily have something of the character of those rocks, and it may be difficult in many instances to indicate the actual line of demarcation, especially where the basal beds have been more or less altered and disturbed by the subsequent folding, faulting, and compression that accompanied the Appalachian uplift.

As defined by Safford, Series II, or the Potsdam group of Tennessee, consists of—

1. The Ocoee conglomerate and slates.
2. The Chilhowee sandstone.
3. The Knox group of shales, dolomites, and limestones.

[1] Geology of Tennessee. Nashville, 1869, pp. 182-226.

[2] Op. cit., pp. 177, 178.

As known to me at the present time the dolomites and limestone are referred to the Lower Silurian, as the equivalent of the Calciferous and Chazy zones of the New York section. This refers the Knox shale to the Upper Cambrian. Prof. Safford states that it is not easy to separate lithologically the *Ocoee sub-group* from the *Chilhowee*, as they often run into each other. The distinction between the latter and the *Knox* is much more apparent.[1]

The Ocoee Conglomerate.—The typical section of the Ocoee conglomerate in the gorge of the Ocoee River, is described by Prof. Safford as follows:

> The strata are well displayed. They are, in general, coarse gray conglomerates, talcose, chlorite and clay slates repeatedly interstratified, all having a semi-metamorphic aspect. The slates predominate, and of these, the greenish and light bluish gray, or the chloritic and talcose varieties, are the most abundant. * * * The middle part of the section presents little conglomerate, but in the upper part it abounds. * * * The lower part of the gorge has several bands of conglomerate.[2]

The thickness of the Ocoee formation was not determined. Provisionally it was estimated to be more than 10,000 feet (p. 186). As shown on the map, the main portion of the Ocoee conglomerate occurs south of Nolichucky River. In Johnson County, in the extreme northeastern corner of the State, it occurs as a narrow band next to the metamorphic series. South of the French Broad River, it occupies a wide belt to the Georgia line. Prof. Safford says it is truly a mountain-making formation.

The recent work of the U. S. Geological Survey has shown that the Ocoee conglomerate is of Silurian age, and it is not to be included with the Cambrian.

The description of the Chilhowee sandstone, and Knox shales and sandstone, will be given in the summary of the present knowledge of the Cambrian rocks of Tennessee.

A résumé of the geology is given in a report upon the resources of Tennessee, by Mr. J. B. Killebrew,[3] which was prepared by Prof. Safford. It is a brief restatement of the character of the formations as described in the "Geology of Tennessee," and the geological map accompanying it is based upon that published in 1869.

When discussing the Silurian age of the Southern Appalachians, Prof. F. H. Bradley considered that the Knox group, of Safford, included the Quebec group and the Calciferous; the Chilhowee sandstone represented the typical Potsdam; and the Ocoee the Lower Potsdam or Acadian group. He also thought that the rocks of North Carolina, south and west of the Little Tennessee, together with the metamorphic area of Georgia, north of a line parallel with and 10 miles south of the Chattahoochee (and *probably* that south of this line), and the entire metamorphic area of Alabama, are *Silurian or newer*, with the possible excep-

[1] Op. cit., p. 182. [2] Op. cit., p. 184.
[3] Resources of Tennessee. Nashville, 1874, pp. 26–46.

tion of two or three small patches not over 10 miles in diameter.[1] A description of sections from Athens and Knoxville, Tennessee, to Murphy, North Carolina, accompany the paper.

The descriptive notes and conclusions of Prof. Bradley were followed, in 1883, by the expression of a somewhat similar view of the age of the Southern Appalachians by Mr. J. B. Elliott,[2] in which he concluded with Bradley that the metamorphosed strata east of the unaltered Ocoee and other "Lower Silurian" rocks were formed of metamorphosed strata of the Knox section.

In the table of formations accompanying Macfarlane's American Geological Railway Guide, Prof. J. M. Safford arranges the formations now referred to the Cambrian in the following descending order:

3*b*. Knox shale.
3*a*. Knox sandstone.
2*b*. Chilhowee sandstone.
2*a*. Ocoee group.

He places as equivalent formations, following Dana's Manual, the Ocoee and the Acadian; the Chilhowee and the Potsdam; the Knox sandstone and the Calciferous; and the Knox shale and the Quebec. This is the classification suggested by Bradley.[3] The Metamorphic group, No. 1, beneath the Ocoee group, is correlated with the Archean.

In an attempt to assign to the proper stratigraphic horizon the rocks referred to the Cambrian group in the United States and Canada, Mr. C. D. Walcott correlated the Knox shale and sandstone with the Potsdam sandstone. The supposed subjacent Chilhowee sandstone and Ocoee conglomerate were referred to a position corresponding to the *horizons* of the Olenellus and Paradoxides faunas.[4] Subsequently, references to the two formations were omitted, pending an investigation of their true stratigraphic position. The discovery, in 1889, of the Olenellus fauna in the shales resting conformably in the Chilhowee series, thus verifying Prof. Safford's section, affirms the correlations of 1883, except that it carries the Middle Cambrian zone above the Chilhowee sandstone and drops the Ocoee, if it proves to be beneath the Chilhowee quartzite, back into the Basal Cambrian.

GEORGIA.

Of the Transition, or older fossiliferous rock formation, Mr. George White said, in 1849, that it has been less explored than any other part of the geology of Georgia.

That part of it which extends from the western base of the primary rocks to the Chattoogatta range of mountains, and which forms the valley of the Oostanaula

[1] On the Silurian age of the Southern Appalachians. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 279, 280.
[2] The age of the Southern Appalachians. Am. Jour. Sci., 3d ser., vol. 25, 1883, pp. 282–298.
[3] Tennessee. (Geological formations.) Macfarlane's Am. Geol. R. R. Guide, 1879, p. 196.
[4] The Cambrian System in the United States and Canada. Washington Phil. Soc., Bull., vol. 6, 1883, p. 100. Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 63.

River, belongs probably to the older series of the New York formations, as those portions which have been examined contain Potsdam sandstones, Calciferous sandrock and limestones of the Trenton group. Very few fossils have been found in it.[1]

This brief description is accompanied by a map, upon which the transition or oldest fossiliferous formations are indicated by one color, in the northwestern corner of the State.

As in the case of North Carolina and Alabama, a long interval elapsed between the first geological survey and the renewal after the conclusion of the civil war. In 1876 Mr. George Little published an account of the geological formations in Georgia, to accompany Janes's Hand-Book of the State. He divides the Lower Silurian into two periods.

The hydromica schists of the copper-bearing series of the Mobile mine and Ducktown, and Ocoee conglomerates and slates along the Ocoee River on the Tennessee line, and on the Etowah River, near Cartersville, are the lowest in position of the rocks in the State, and form a group of (2) Primordial rocks corresponding to what is called the (2*a*) Acadian epoch in Canada. The conglomerate is made up of feldspar and a bluish quartz. The slates are hard and siliceous. This group of rocks is overlaid in the Cohutta Mountains, and on Pine Log Mountain in Bartow County, by a sandstone called the Chilhowee, from a mountain of that name in Tennessee, corresponding to the Potsdam sandstone in New York, * * * and belongs also to the (2) Primordial period and to the (2*b*) Potsdam epoch. This sandstone appears in the north of Haralson and Paulding counties, and in Yonah Mountain, White County, and Tallulah Mountain, Habersham County, being at all these places altered into gneiss by metamorphism.

The next period, called (3) Canadian, embracing the (*a*) *Calciferous* * * * of New York, * * * the (*b*) *Quebec* epoch in Canada, and the (*c*) *Chazy* limestone of New York, is represented by impure sandstones and cherty dolomitic limestones in the northwestern counties; by a sandstone on the western slope of the Cohutta Mountains; and in the metamorphic region to the eastward and southward by calcareous schists, hydromica schists, marble, and itacolumite of the Quebec epoch, and by calcareous schists of the (*a*) Calciferous epoch.[2]

This arrangement follows that of Prof. Safford in Tennessee except that the Knox sandstone and the Knox shales are not included.

In a work on "The Commonwealth of Georgia," prepared under the direction of J. T. Henderson[3] in 1885, there is a general description of the geology of the State. The Acadian or the Ocoee and Chilhowee formations and the Knox shales are all recognized. Reference to this description will be made in the summary of our present knowledge of the Cambrian rocks of Georgia.

In the Tenth Census report a brief résumé of the geology is given with relation to the soils formed from their decomposition. In this Mr. A. R. McCutchen states that the aggregate thickness of the groups, estimating the Primordial at 8,000 feet, and taking the maximum thickness of each of the higher groups, amounts to about 20,000 feet. The Primordial and Calciferous are followed by rocks referred to the Quebec

[1] Statistics of the State of Georgia. Savannah, 1849, p. 22.

[2] Little, George. Geological survey of the State of Georgia. Hand-book of the State of Georgia, with geologic map of State, by T. P. Janes, 1876, p. 37.

[3] Geology (of Georgia). The Commonwealth of Georgia. The country; the people; the productions. Atlanta, 1885, pp. 73–117.

group; first by about 2,400 feet of shales, and then by 5,000 feet of cherty limestones[1]. Combining these estimates we have 8,000 feet of Primordial and 2,400 feet of shales corresponding in position to the Knox shales, which gives a total of 10,400 feet for the Cambrian rocks of Georgia, as estimated. This paper is accompanied by a section crossing Dade, Walker, and Gordon Counties in northwestern Georgia. The stratigraphic relations of the Cambrian rocks are shown as they occur in Gordon County.

A geological section of the Cambrian rocks of northwestern Georgia has recently been published by Mr. C. Willard Hayes of the U. S. Geological Survey. It is referred to in the description of the Cambrian rocks of Georgia.[2]

ALABAMA.

The report of Prof. M. Tuomey for 1858[3] contains a very general description of the formations of the State, and on the accompanying map the Silurian and Devonian formations are included under one color, so that it is impossible to differentiate that portion of the Silurian formation which has subsequently been found to belong to the Cambrian group. In a general north and south section, showing the disposition of the strata, the Silurian and Devonian rocks are represented as unconformably subjacent to the Coal Measures and mountain limestone.

A long interval elapsed between the work of Prof. Tuomey and the organization of the geological survey under Prof. Eugene A. Smith. In the report of progress of the latter, for the year 1875, a general description of the geological formations of Bibb, Shelby, Talladega, and Calhoun Counties is given. In this area there is a large development of metamorphic rocks described by Prof. Smith in the report for 1874.[4] Of this series he says:

> On the southeastern border of the Silurian formation in Alabama, from the Georgia line to the northeast corner of Chilton County, a stratum of crystalline limestone, almost pure carbonate of lime, may be traced by its occasional exposures. * * * Succeeding this limestone and *apparently* overlying it conformably * * * is a series of semi-metamorphic strata between 15,000 and 20,000 feet in thickness, striking northeast and southwest and dipping at high angles (45°) southeast. This series, beginning below, is composed of greenish gray hydro-mica slates (talcoid slates, nacreous argillites, talcose slates), passing upwards into a conglomerate by enclosing lumps of quartz; these slates are succeeded by thick beds of quartzite, alternating with greenish chloritic schists. The quartzite in places is a thin-bedded siliceous slate, again a thick-bedded quartzose conglomerate, and still again a laminated quartzose or arenaceous rock, not very coherent, and enclosing small grains of quartz.

[1] Northwest Georgia. (Geologic description.) Tenth Census U. S., vol. 6; Report on Cotton Production in the United States, Part 2, 1884, p. 287.

[2] The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America. Vol. 2, Feb., 1891, p. 143, pl. 3.

[3] Second biennial report on the geology of Alabama. Montgomery, 1858, pp. 168.

[4] Geological survey of Alabama. Report of progress for 1874. Montgomery, Alabama, 1875, pp. 21-25.

This series of quartzites in their several varieties makes up the main body of the Blue Mountains range in Alabama.

These strata are the probable equivalents in Alabama of the Ocoee conglomerates and slates of Prof. Safford, of the Tennessee survey, by him referred to the Silurian age underlying the Potsdam. By Prof. Sterry Hunt the entire system of crystalline schists has been referred to pre-Silurian and pre-Cambrian age. My own observations in the field while inclining me to the latter view, have not been sufficiently extended to enable me to form an independent judgment on this point. * * * Mr. F. H. Bradley refers to the Lower Silurian all the metamorphic rocks of North Carolina as far east as Franklin.[1]

This metamorphic belt is apparently the same as the altered Silurian rocks of Prof. Bradley, as stated by Prof. Smith, and also of the altered rocks forming the northward extension of the Blue Ridge through Tennessee, Virginia, and Maryland into Pennsylvania, where it forms the South Mountain.

In the report for 1875 Prof. Smith states that he has followed the Tennessee subdivisions as found in Prof. Safford's published volume.[2] Under the caption of "Lower Silurian," the Primordial or Cambrian period is divided into (1) Acadian epoch and (2) Potsdam epoch. The Acadian slates and conglomerates of Talladega County are considered to be the exact equivalents of Safford's Ocoee slates and conglomerates.[3] The direct superposition of the sandstone referred to the Potsdam, upon the Acadian slates, is not well shown in Alabama. The formation consists of fine-grained conglomerate, heavy-bedded sandstone, and sandy shale. The most characteristic markings of the rocks of this formation are the sandy rods, caused by the filling in with sand of the burrows of a marine worm, *Scolithis linearis*.[4]

The Knox sandstone and Knox shales are referred to the Canadian period, thus following Prof. Safford's arrangement in Tennessee. The Knox sandstone is considered to rest upon the sandstone referred to the Potsdam, but no contact of the two formations in such a position is known to him. The sandstone is a calcareous sandstone associated with hard calcareous shales.

The Knox shales are very similar to those of Tennessee, and succeed conformably the Knox sandstone. The line between the Knox shale and the Knox dolomite is difficult to draw since the lower part of the dolomite contains beds of blue limestone similar to those in the upper part of the shale. This report contains much detailed information of the strata referred to the Cambrian in Alabama, and will be principally used in the description of the Cambrian rocks of that State.

In a paper on the iron ores of Alabama, with special reference to their geological relations, Prof. Smith states that the Potsdam sandstone frequently contains large amounts of iron, principally as *limonite*. In the Kahatchee hills, in Talladega County, the sandstone is sometimes impregnated with iron in the form of *specular ore* or as *magnetite*.

[1] Op. cit., pp. 21, 22.
[2] Report of progress of the geological survey of Alabama for 1875. Montgomery, 1876, pp. 7, 8.
[3] Op. cit., p. 127. [4] Op. cit., p. 14.

Small beds of limonite are found in the Knox sandstone and Knox shales.[1] In 1878 the same writer published an outline of the geology of Alabama accompanied by a map of the State, based upon that of Tuomey, published in 1858. Of the age of the metamorphic rocks he says that until further examination he leaves the question of age an open one, except in two instances, in which he believes at least a part of them are metamorphosed Silurian beds.[2]

The classification and general description of the formations is essentially the same as that contained in the reports of 1874–'75.

In a report on the physico-geographical and agricultural features of Alabama, Prof. Smith notes the character of soil produced by the rocks of the different formations, from the Potsdam to the Coal measures.[3] This paper was also printed in a general description of the State of Alabama, in vol. 6, of the Tenth Census.[4]

A brief description of the Cambrian rocks of Alabama is given by Prof. Eugene A. Smith, in a report on the geological structure and description of the valley region adjacent to the Cahaba coal field.[5] A summary of it is given in the description of the Cambrian rocks of Alabama.

References are made to the geology of Alabama, in a general way, by Dr. T. S. Hunt, Prof. Smith, and various mining engineers, but I have not, with the exception of the preceding notice, met with original contributions to the knowledge of the Cambrian rocks, since the publication of Prof. Smith's detailed description.

PALEONTOLOGY.

NORTHERN APPALACHIAN DISTRICT.

The first discovery of fossils in rocks, now referred to the Lower Cambrian, was made by Dr. Asa Fitch.[6] In the summer of 1844 he found trilobites in a black slate in Washington County, New York, which was referred by Dr. E. Emmons to the Taconic slate or Argillite (1 of Eaton). Dr. Fitch sent the fossils to Dr. Emmons, who described from them two species of trilobites under the names of *Atops trilineatus* and *Elliptocephalus asaphoides*.[7] Believing that the rocks in which the trilobites occurred were unconformably beneath the Potsdam sandstone,

[1] The iron ores of Alabama, with special reference to their geological relations. Am. Assoc. Proc., vol. 27, 1878, pp. 247, 248.

[2] Outline of the geology of Alabama. Berney's Hand-Book of Alabama, 1878, p. 140.

[3] (Geological features and divisions of Alabama.) Geol. Survey of Alabama. Report for 1881 and 1882, 1883, pp. 178–181; 192–210.

[4] General description of the State of Alabama. Tenth Census U. S., vol. 6. Report on cotton production in the United States, part 2, 1884, pp. 19–69.

[5] Geological Survey of Alabama. Report on the Cahaba coal field, part II, 1890, pp. 148–150. (Issued January, 1891.)

[6] A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850, p. 865.

[7] The Taconic System, based on observations in New York, Massachusetts, Vermont, and Rhode Island, p. 20, 21 Albany, 1844.

Dr. Emmons called them the oldest known fossils in America. In the same work Dr. Emmons described *Fucoides rigida*, *F. flexuosa*, *Gordia marina*, *Diplograptus simplex*, and others of Silurian (Ordovician) age that he referred to the Taconic system.

The second description of fossils was made by Prof. James Hall in the Paleontology of New York, vol. 1, 1847. Under the title "Description of fossils of the Hudson River group," the following species were described as new: *Orbicula cælata* (p. 290), *Orbicula? crassa* (p. 290), *Avicula? desquamata* (p. 292), *Theca? triangularis* (p. 313), *Metoptoma? rugosa* (p. 306), *Palæophycus virgatus* (p. 263), and *Agnostus lobatus* (p. 258). A description and figures are given of *Olenus asaphoides*, Emmons, on pages 256, 257, pl. 67, figs. 2a–c. In a later publication[1] he identified Conocephalus and Olenus from the Red Sandrock formation of Highgate, Vermont, but did not assign them to a geologic horizon. In studying a collection sent to him by Rev. Zadock Thompson, Prof. Hall determined and described *Olenus thompsoni*, *O. vermontana*, *Peltura* (*Olenus*) *holopyga*, referring them to the Hudson River group.[2] He supported this reference by the statement that Sir William Logan referred the shales containing the fossils to the upper part of the Hudson River group. In 1860[3] he proposed the genus Barrandia, to include *Olenus thompsoni* and *O. vermontana*. The genus Bathynotus was established to include *Olenus* (*Peltura*) *holopyga*. In 1861[4] the reference of these trilobites was changed from the Hudson River group to the Quebec group; and a little later a strong defense was made of the reference of the fossils of the Georgia slates to the Hudson River and Quebec groups, the authority of Sir William E. Logan for the stratigraphic position of the rocks being cited.[5] Discovering that the proposed generic name, Barrandia, was preoccupied, he substituted the name Olenellus in 1862.[6] This is the first introduction of the name which is now given to the Lower Cambrian fauna.

The last reference of Prof. Hall to the fauna is the proposal of the genus Discinella for what he considered to be a small brachiopod, but which investigation proves to be the operculum of *Hyolithellus micans*.[7]

In notes on the fossils of Washington County, Dr. Asa Fitch[8] de-

[1] Hall, James: Letter on certain fossils of the red sandrock of Highgate. 3d Annual Report on the Geology of the State of Vermont. Burlington, 1847, p. 31.

[2] Remarks upon the trilobites of the shales of the Hudson River group. Paleontology of New York, vol. 3, supplement to vol. 1, 1859, pp. 525–529.

[3] Note upon the trilobites of the shales of the Quebec group in the town of Georgia, Vermont. 13th Annual Report State Cab. Nat. Hist., 1860, pp. 113–119. Report upon the geology of Vermont, vol. 1, 1861, pp. 367–372.

[4] Hall, James; Correction for the 13th Ann. Rep. 14th Ann. Rep. State Cab. Nat. Hist., 1861, p. 110.

[5] Hall, James: Letter on the Primordial of America. Soc. géol. France, Bull., 2e sér vol. 19, 1862, pp. 725–734.

[6] Supplementary note to 13th Ann. Rep. State Cab. Nat. Hist. N. Y. 15th Ann. Rep. State Cab. Nat. Hist. N. Y., 1862, p. 114.

[7] Notes on some new and imperfectly known forms among the brachiopoda, etc. 23d Ann. Rep. N. Y. State Mus. Nat. Hist., 1873, p. 246.

[8] A Historical, Topographical, and Agricultural Survey of the County of Washington. Trans. N. Y. State Agric. Soc. for 1849, 1850.

scribes *Palæophycus rectus* (p. 862), *Buthotrephis (?) asteroides* (p. 863), *Helminthoidichnites tenuis* (p. 866), from the slates now referred to the Lower Cambrian. He also mentions *Palæophycus virgatus* Hall, *Buthotrephis (?) flexuosus* Emmons (p. 862), and *Gordia marina* of Emmons as *Helminthoidichnites marina* (p. 868).

The fauna of the "Red sandrock" of Vermont was first discovered by Prof. C. B. Adams in 1847,[1] who sent the specimens to Prof. James Hall. The latter identified Conocephalus, but did not refer the fossils to any geological horizon. Prof. Adams in 1848[2] mentions the Conocephalus and also an Atrypa, like *Atrypa hemispherica* (equivalent to *Camerella? antiquata* Billings).

Mr. E. Billings, as paleontologist to the Geological Survey of Canada, took up the study and correlation of the older paleozoic faunas, and was the first to assign the fossils described by Prof. Hall to a pre-Potsdam horizon and to correlate the strata containing them with the Upper Primal sandstones of Pennsylvania, and the limestones of the Straits of Belle Isle.[3]

In 1861 he described a number of Lower Silurian fossils from the "Potsdam group" of Vermont and assigned the following species to the horizon of *Paradoxides thompsoni* of Hall: *Palæophycus congregatus*, *P. incipiens*, *Obolella* (*Kutorgina*) *cingulata*, *Orthisina festinata*, *Camerella antiquata*, *Conocephalites adamsi*, *C. teucer*, *C. vulcanus*, *C. arenosus*.

A little later he published a note on the "Red sandrock" formation of Vermont,[4] in which he refers the formation to the base of the Lower Silurian somewhere within the horizon of the Potsdam and identifies Conocephalites from the formation. In reprinting in 1865 the article published in 1861[5] he correlates the primordial fauna of the "Red sandrock" of Vermont with that of Newfoundland and Labrador, and refers them to the Potsdam group, stating that there is no paleontological evidence of precise similarity of age, but the general affinities and scope of the fossils and the physical relations of the rocks prove that there can be no great difference.

Under the title "On some new species of fossils from the limestone near Point Levi, opposite Quebec,"[6] Mr. Billings described the fauna collected by the Geological Survey of Canada from the limestone conglomerate. He designated the rocks simply as Limestone Nos. 1, 2, 3, and 4, not recognizing at the time that the bowlders were transported and imbedded in a secondary deposit; and that the fossils in the bowl-

[1] 3d Annual Report on the geology of the State of Vermont. Burlington, 1847, pp. 31.

[2] On the Taconic rocks. Am. Jour. Sci., 2d ser., vol. 5, 1848, p. 109.

[3] Paleozoic fossils, vol. 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1860–1865. Montreal, 1865, pp. 1, 2.

[4] Billings, E.: On the age of the Red sandstone formation of Vermont. Am. Jour. Sci., 2d ser., vol. 32, 1861, p. 232.

[5] Billings, E.: Paleozoic Fossils, vol. 1, 1865, p. 371.

[6] On some new species of fossils from the limestone near Point Levi, opposite Quebec. Canadian Nat., vol. 5, 1860, pp. 301–324.

ders were of Upper Cambrian age while those of the limestone matrix, which resembled in character the limestone of the bowlders, was deposited in situ, and carried the Calciferous fauna. As far as I have been able to separate the species by a study of the material from the bowlders and the limestone matrix the following may be referred to the Upper Cambrian or Potsdam fauna: *Camerella calcifera* ?, *Agnostus americanus*, *A. orion*, *A. canadensis*, *Dikelocephalus magnificus*, *D. planifrons*, *D. belli*, *D. oweni*, *D. megalops*, *D. cristatus*, *Arionellus cylindricus*, *A. subclavatus*, *Menocephalus sedgwicki*, *M. globosus*, *Conocephalites zenkeri*, *Asaphus illænoides*.

Mr. T. Devine, of Quebec, having discovered several nearly perfect trilobites in the conglomerate limestone at Point Levi, described two species of them. One as *Olenus ? logani*,[1] the other as *Menocephalus salteri*.[2] In a foot-note accompanying the description of *Olenus ? logani* Mr. Billings states that the species is unquestionably congeneric with those which he had described as *Dikelocephalus belli* and *D. oweni* from the same locality.

To the species described from Point Levi in 1860 Mr. E. Billings added in 1865[3] *Dikelocephalus devinei*, *D. hisingeri*, *D. affinis*, *D. sesostris*, *D. selectus*, and *D. pauper*. He also figured in this connection *Olenus ? logani*, Devine and *Menocephalus salteri*, Devine.

In 1872 Mr. Billings returned to the study of the fossils of the older Paleozoic rocks and described one new genus and several species found in bowlders, of several beds of conglomerate at St. Simon, below Quebec, as follows: The genus Obolella and the species *Obolella gemma* and *O. circe*, *Platyceras primævum*, *Hyolithes americanus*, *H. communis*, *H. princeps*, *H. micans*. On page 240 of the same volume the genus Hyolithellus is proposed for the species *Hyolithes micans;* and on page 351 he notes the discovery of *Salterella pulchella* in the Winooski marble of Vermont.[4]

The Cambrian fauna of northern Vermont was further enlarged in 1884 by Prof. R. P. Whitfield[5] describing *Orthisina orientalis* (p. 144), *Nothozoa vermontana* (p. 144), *Dikelocephalus, marcoui* (p. 150), and *Angelina hitchcocki* (p. 148); all of which were referred by him to the horizon of the Potsdam sandstone.

The oldest Phyllopod crustacean, *Protocaris marshi*, was described by Mr. C. D. Walcott[6] in 1884 from the Georgia slates of Vermont,

[1] Description of a new trilobite from the Quebec group. Canadian Nat., vol. 8, 1863, p. 95.

[2] Op. cit., p. 210.

[3] Paleozoic Fossils, vol. 1, 1865, pp. 195–200.

[4] On some new species of Potsdam fossils. Canadian Nat., vol. 6, new ser., 1872, pp. 213–226, 240.

Note on the discovery of fossils in the "Winooski Marble" at Swanton, Vermont. Am. Jour. Sci., 3d ser., vol. 3, 1872, p. 145. Canadian Nat., new ser., vol. 6, 1872, p. 351.

[5] Notice of some new species of Primordial fossils in the collections of the Museum, and correction of previously described species. Am. Mus. Nat. Hist. Bull., vol. 1, 1884, pp. 139–154.

[6] On the Cambrian faunas of North America; preliminary studies. U. S. Geol. Survey, Bull. No. 10, 1884, p. 50.

where it is found in association with *Olenellus thompsoni* and *O. vermontana*. The latter was referred to the new genus Mesonacis in 1885.[1]

Mr. S. W. Ford began, about 1868, a study of the rocks and fossils of the hills east of Troy, New York, from which vicinity the first fossils of the Olenellus fauna, found in New York, were obtained. These were described by Prof. Hall, in 1847, and referred by him to the Hudson River group. Entering into correspondence with Mr. E. Billings, and comparing the fauna he found at Troy with that from below Quebec, referred by Mr. Billings to the Lower Potsdam, he concluded that the strata containing the fauna at Troy should be referred to an equivalent horizon. In his first paper[2] he mentions finding eighteen species, eight of which are referred to described species and ten remained to be described. Mr. Ford published a number of papers from 1871 to 1885,[3] in which he described the rocks, and fossils found in them, that occur near Troy, and also a little south of Schodack landing, in Columbia County, N. Y. The fossils described by him are: *Protocyathus rarus*, *Archæocyathus rensselæricum*, *Obolella nitida*, *Scenella retusa*, *Hyolithes emmonsi*, *H. impar*, *Agnostus nobilis*, *Leperditia troyensis*, *Microdiscus meeki*, *M. speciosus*, and *Solenopleura nana*. One of the most interesting of Mr. Ford's studies is that on the embryonic development of *Olenellus asaphoides*. From the data thus obtained he decided that the Olenellus fauna followed the Paradoxides fauna in time.[4]

---

[1] Paleozoic notes; new genus of Cambrian trilobites Mesonacis. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 328–330.

[2] Ford, S. W.: Notes on the primordial rocks in the vicinity of Troy, New York. Am. Jour. Sci., 3d ser., vol. 2, 1871, pp. 32–34. Canadadian Nat., new ser., vol. 6, 1872, pp. 209–212.

[3] Descriptions of some new species of primordial fossils. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 419–422.

On some new species of fossils from the Primordial or Potsdam group of Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 5, 1873, pp. 211–215.

Remarks on the distribution of the fossils in the Lower Potsdam rocks at Troy, New York, with descriptions of a few new species. Am. Jour. Sci., 3d ser., vol. 6, 1873, pp. 134–140.

Note on the discovery of a new locality of primordial fossils in Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 204–206.

On additional species of fossils from the primordial of Troy and Lansingburg, Rensselaer County, New York. Am. Jour. Sci., 3d ser., vol. 11, 1876, pp. 369–371.

Note on Microdiscus speciosus. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 141, 142.

On some embryonic forms of trilobites from the primordial rocks at Troy, New York. Am. Jour. Sci., 3d ser., vol. 13, 1877, pp. 265–273.

Two new species of primordial fossils. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 124–127.

Note on *Lingulella cælata*. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 127–129.

Note on the development of *Olenellus asaphoides*. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 129, 130.

On certain forms of Brachiopoda occurring in the Swedish primordial. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 364–366.

Note on the trilobite *Atops trilineatus* of Emmons. Am. Jour. Sci., 3d ser., vol. 19, 1880, pp. 152, 153.

Remarks on the genus Obolella. Am. Jour. Sci., 3d ser., vol. 21, 1881, pp. 131–134.

On additional embryonic forms of trilobites from the primordial rocks of Troy, New York. Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 250–259.

Note on the discovery of primordial fossils in the town of Stuyvesant, Columbia County, New York. Am. Jour. Sci., 3d ser., vol. 28, 1884, pp. 35–37.

[4] Embryonic forms of trilobites from the primordial rocks of Troy, New York. Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 250–259.

In 1886 Prof. William B. Dwight announced the discovery of the fauna of the Potsdam zone in limestone near Poughkeepsie, New York. He gives a list of eleven species as follows:[1]

Lingulepis pinnaformis.
Lingulepis minima.
Lingulepis acuminata (probably).
Obolella (Lingulella) prima.
Obolella sp.
Platyceras sp.
Ptychoparia (Conocephalites) n. sp.
Dikelocephalus sp.
Ptychaspis sp.
Stromatocerium ?
Remains of crinoid columns.

The review of the Olenellus or Lower Cambrian fauna by Mr. C. D. Walcott in 1886[2] resulted in the description of the following species from Vermont: *Climacograptus ? emmonsi* (p. 93), *Orthisina transversa* (p. 121), *Scenella ? varians* (p. 127) and *Microdiscus parkeri* (p. 157). This was followed in 1887[3] by an account of the discovery of a number of new species of fossils from the Upper Taconic slate of Emmons in Washington County, New York. The new species described are as follows:

Lingulella granvillensis.
Linnarssonia taconica.
Orthis salemensis.
Modiolopsis (??) prisca.
Hyolithellus micans, var. rugosa.
Aristozoa rotundata.
Leperditia (I) dermatoides.
Microdiscus connexus.
Olenoides fordi.
Solenopleura (?) tumida.
Ptychoparia (?) fitchi.
P. (?) clavata.

In describing a section of the Cambrian rocks in northern Vermont notice is taken by Mr. Walcott of the occurence in the upper beds of a fauna resembling that of the Upper Cambrian or Potsdam zone.[4]

In a paper announcing the discovery of the fossiliferous strata of the Paradoxides zone at Stissing Mountain, Dutchess County, New York, Prof. W. B. Dwight[5] identified *Hyolithes billingsi ?* (p. 143) and described as new *Leperditia ebenina* (p. 144), *Kutorgina stissingensis* (p. 145), and *Olenoides stissingensis* (p. 147), correlating the fauna with that of the Middle Cambrian of the Rocky Mountain province.

In a review of the Lower Cambrian fauna by Mr. C. D. Walcott, prepared for the Tenth Annual Report of the U. S. Geological Survey, a number of new species and genera are proposed, most of which are described in a preliminary paper published in the Proceedings of the U. S. National Museum.[6] These are *Archæocyathus dwighti* (p. 34), *Plan-*

[1] Recent explorations in the Wappinger Valley limestone of Dutchess County, New York. No. 5: Discovery of fossiliferous Potsdam strata at Poughkeepsie, New York. Am. Jour. Sci., 3d ser., vol. 31, 1886, p. 131.

[2] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886.

[3] Fauna of the "Upper Taconic" of Emmons, in Washington County, New York. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 187-199.

[4] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 17, 19.

[5] Recent explorations in the Wappinger limestones and other formations of Dutchess County, New York. Am. Jour. Sci., 3d ser., vol. 38, 1889, pp. 139-153.

[6] Descriptive notes of new genera and species of the Lower Cambrian or Olenellus zone of North America. U. S. Nat. Mus. Proc., vol. 12, 1889, pp. 33-46.

olites annularius (p. 34), *Agnostus desideratus* (p. 39), and *Zacanthoides eatoni* (p. 45), from Washington County, and *Camerella minor* (p. 36), from Dutchess County, New York; *Kutorgina cingulata*, var. *swantonensis* (p. 36) from northern Vermont.

In 1890 the following new species were described:[1] *Trachyum vetustum*, Dawson, from Metis, Canada; *Phyllograptus cambrensis*, from Georgia, Vermont; *Stenotheca* (?) *rugosa* var. *acuta-costa*, *erecta*, and *levis*, *Platyceras dawsoni*, from St. Simon, Quebec; *Olenoides ellsi*, from below Quebec, Canada; *O. desiderata*, from Highgate Springs, Vermont; *Conocoryphe reticulata*, from Washington County, New York; *Ptychoparia metisensis* and *Agraulos redpathi*, from below Quebec.

SOUTHERN APPALACHIAN DISTRICT.

NEW JERSEY, ETC.

The Cambrian fauna of New Jersey, Delaware, Pennsylvania, Maryland, and Virginia is thus far restricted to the presence of the Annelid boring *Scolithus linearis*. It is extremely probable that trilobites and other fossils will be found in the Granular Quartzite series, or the basal quartzite and the immediately superjacent shales and limestones.

TENNESSEE.

The Cambrian fauna of Tennessee consists of *Scolithus linearis* tubes found in the Chilhowee sandstone; while in the shales just above the sandstone occur numerous Annelid trails, a species of Hyolithes like *H. americanus*, an Ostracod crustacean, *Isoxys chilhoweana*, and a species of Olenellus closely allied to *Olenellus thompsoni* and *O. asaphoides* in that portion of the head preserved.[2]

From the upper part of the Knox shale Prof. J. M. Safford[3] has named, without description or illustration, several species, as follows:

Crepicephalus similis, Safford.
roanensis, Safford.
tennesseensis, Safford.
Lonchocephalus fecundus, Safford.
Agnostus arcanus, Safford.
Lingula prima? Conrad.

Quite a large fauna occurs at this horizon in the collections of the Geological Survey which has not yet been studied with care. As far as examined it appears to be of the type of the Upper Cambrian of the Mississippi Valley.

[1] Walcott, C. D.: The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep. U. S. Geol. Surv., 1890, pp. 598–655.
[2] Ibid., p. 626.
[3] Geology of Tennessee. Nashville, 1869, p. 212.

GEORGIA.

A trilobite was sent to the great exhibition in London in 1851 said to be found somewhere in Georgia. Mr. J. W. Salter[1] describes the species as *Conocephalus antiquatus*, comparing it with *C. striatus* of the Primordial rocks of Bohemia. The exact locality from which this species came was not known until collections were made in northwestern Georgia by the U. S. Geological Survey in 1885. It was then found to be associated with a fauna much like that of the Middle Cambrian fauna of the Rocky Mountains. The specimens occur in and upon siliceous concretions imbedded in the Coosa Valley shales of Floyd County and to the southwest in Alabama.

A second species was described by Mr. C. D. Walcott in 1889 as *Olenoides curticei*. It occurs on and in siliceous concretions found in the shales of the Coosa Valley.[2]

ROCKY MOUNTAIN PROVINCE.

The area of Cambrian rocks in this province includes the Cambrian outcrops of northern and western Utah, Nevada, eastern Idaho, and the Gallatin River district of Montana. The Canadian extension is considered separately.

UTAH AND NEVADA.

During the progress of the geological survey of the fortieth parallel, under the charge of Mr. Clarence King, Prof. F. B. Meek described two species of trilobites from Antelope Spring, Nevada, *Pardoxides* (?) *nevadensis* and *Conocoryphe* (*Conocephalites*) *kingi*, referring them to the Primordial zone.[3]

In the following year Prof. J. D. Whitney exhibited before the California Academy of Sciences some fossils that had been collected by Mr. J. E. Clayton near Eureka, Nevada. He referred them to the age of the Potsdam sandstone, identifying *Agraulos oweni*, M. and H., or a species closely resembling it; *Lingulepis prima*, *Obolella*, *Conocoryphe*, *Paradoxides*, etc.[4] A note on the occurrence of the Primordial fauna in Nevada was also sent to the American Journal of Science by Prof. Whitney. In this he mentions the occurrence of certain Primordial species, and the persistence with which these constantly recurring trilobites and brachiopods are found at various localities. In Bohemia they occur in argillaceous shales; throughout the United States, from New York to the Rocky Mountains, in the Potsdam sandstone, or in shales or slates; in Texas, and now in Nevada, in limestones.[5]

[1] On the fossils of the Lingula-flags or "Zone Primordiale." Quart. Jour. Geol. Soc., London, vol. 15, 1859, p. 554.

[2] Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. National Museum Proc., vol. 11, 1889, p. 443.

[3] Descriptions of fossils collected by the United States Geological Survey, under the charge of Clarence King, esq. Phila. Acad. Sci., Proc., vol. 22, 1870, pp. 62–64.

[4] [On some fossils from Eureka, Nevada.] California Acad. Sci., Proc., vol. 4, 1871, p. 200.

[5] Note on the occurrence of the "Primordial Fauna" in Nevada. Am. Jour. Sci., 3d ser., vol. 3, 1872, p. 85.

In the Sixth Annual Report of the U. S. Geological Survey of the Territories, Prof. F. H. Bradley states that his section along the Wasatch range of Utah is not complete. The bedded quartzites, referred to the Potsdam from the character of the overlying strata, rest unconformably upon the "Metamorphic." No fossils were found in the quartzite or in the superjacent gray and calcareous shales. The limestone above the shales is referred to the Niagara.[1]

During the progress of the survey west of the one hundredth meridian Mr. G. K. Gilbert visited the Antelope Spring locality, discovered by Mr. J. E. Clayton, and mentioned by Prof. Whitney when calling attention to the Primordial fossils found there. The fauna occurs in a blue gray, calcareous shale, some 200 feet in thickness. In addition to the species described by Mr. Meek, he collected *Bathyurellus* (*Asaphiscus*) *wheeleri*, Agnostus, and Discina. Beneath the blue gray shales is a massive gray limestone, 900 feet in thickness, superjacent to a vitreous sandstone.[2] From our present knowledge of the Cambrian rocks in Nevada, the gray limestone, blue gray shales, and an upper gray limestone some 200 feet in thickness all belong to the Cambrian.

The section of the Oquirrh range at Ophir City, Utah, was found by Mr. Gilbert to have, near its base, 100 feet of light gray limestone containing Conocoryphe and Dikelocephalus. Subjacent to this a massive limestone with coralline mottling extends downward some 300 feet to an argillaceous shale, in which Mr. J. E. Clayton found *Olenus gilberti*.[3] At the south end of the Timpahute range of eastern Nevada Mr. Gilbert also discovered a succession of shales and sandstones, in which he found Conocoryphe in the lower portion, and above, a band of purple ripple-marked vitreous sandstone, with bands of siliceous shale.[4] The descriptions of *Olenus* (*Olenellus*) *gilberti* and *O.* (*O.*) *howelli* of Meek are printed on pages 182 and 183 of Mr. Gilbert's report.

In the same volume Mr. E. E. Howell states that at Pioche, Nevada, the massive quartzite forming the base of the section is subjacent to about 400 feet of arenaceous and calcareous shales of a reddish yellow color, containing in the more calcareous portions several types of Primordial fossils in great abundance.[5] From the material found by Mr. Howell, Mr. Meek described two species of trilobites, *Olenellus howelli* and *O. gilberti*.

On the map accompanying the Wheeler survey reports, published in 1874, the Cambrian rocks are included under the same color with those of the Silurian.

---

[1] Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 194.

[2] Report on the geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th meridian, in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 167.

[3] Op. cit., pp. 166, 167.

[4] Op. cit., p. 169.

[5] *Report* on the geology of portions of Utah, Nevada, Arizona, and New Mexico examined in the years of 1872 and 1873. Rept. Geog. and Geol. Expl. Sur. west of the 100th mer., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 258.

A reconnaissance of the northwestern portion of the Wasatch Mountains in Utah was made by Prof. F. H. Bradley in 1872. He found that the crest and eastern slopes are composed of quartzite and limestone. The former, a white and ferruginous quartzite, 1,500 feet in thickness, was referred to the Potsdam, and a band of superjacent gray calcareous shale, 1,000 to 1,200 feet thick, to the Lower Silurian. The section as arranged by Prof. Bradley is as follows:[1]

3. Blue and gray magnesian limestones, partly pebbly, 1,900 to 2,000 feet	Upper ? and Lower Silurian.
4. Gray calcareous shales, 1,000 to 1,200 feet	
5. White and ferruginous quartzite, base pebbly, 1,500 feet	Potsdam.

Under the title of "Paleozoic subdivisions of the fortieth parallel" Mr. Clarence King describes the strata referred to the Cambrian system. This includes 12,000 feet of quartzites and argillites in the Big Cottonwood Cañon section of Utah, superjacent to which is a shaly zone some 75 feet in thickness, carrying well defined Primordial fossils. He says:

Comparing the quartzites and argillites with those of the Cambrian section in Wales, the likeness is too great to pass unnoticed, and in view of the enormous developments of these low-lying rocks, as compared with the Silurian lying above the Primordial horizon, I have determined to draw a line at the upper limit of the Primordial period to include the uppermost members of the Potsdam epoch and to consider the whole underlying conformable series as Cambrian down to the point of their nonconformity with the Archean. In the extreme east of our work, in the region of the Rocky Mountains, the Cambrian formation is of variable thickness and nowhere reaches an exposure of over 100 feet. In middle Nevada the uppermost zone of the Cambrian, equivalent to the calcareous and argillaceous shales of the Wahsatch, is an immense body of dark limestones at least 3,000 feet in thickness carrying Primordial fossils throughout; the downward continuation of the series being there entirely hidden by the overlying Quaternary desert.[2]

This general definition of the Cambrian is accompanied by a list of the fossils described by Messrs. Hall and Whitfield.

The Cambrian section of Big Cottonwood Cañon referred to by Mr. King is described by Mr. S. F. Emmons with more detail.[3] On the west side of Box Elder Peak, near the little village of Call's Fort, in a body of dark blue argillaceous slates in the lower portion of the Ute limestone body, Mr. Emmons states that the following fossils of the Quebec group were found: *Dikelocephalus wasatchensis*, *D. gothicus*, *Crepicephalus* (*Loganellus*) *quadrans*, and *Lingulepis ella*.[4] In the section on Muddy Cañon, within 25 feet of the base of the series, occurs a body of calcareous shales, interstratified with narrow beds of a dark,

[1] Explorations of 1872; United States Geological Survey of the Territories, under Dr. F. V. Hayden; Snake River division. Am. Jour. Sci., 3d ser., vol. 6, 1873, p. 194.

[2] King, Clarence: Paleozoic subdivisions on the 40th parallel. Am. Jour. Sci., 3d ser., vol. 11, 1876, p. 476.

[3] Hague, Arnold, and S. F. Emmons: Descriptive Geology. U. S. Geol. Expl. of the Fortieth Par.; vol. 2, 1877, pp. 366, 367.

[4] Op. cit., p. 405.

fine-grained limestone, which contains abundant organic remains. Two species were recognized, *Dikelocephalus quadriceps* and *Conocephalites subcoronatus*.[1] The reference of the fossils at Call's Fort and Muddy Cañon to the Quebec group was on the authority of the paleontologists. More recent studies of this fauna, by Mr. Walcott, in connection with the section at Big Cottonwood Cañon prove that the fauna mentioned at these localities is a portion of the Middle Cambrian fauna, and that the Upper Cambrian strata are absent in the section by nondeposition.

In the Weber Cañon region of the Wasatch Mountains, 800 to 1,000 feet beneath limestones referred to the Devonian, there were obtained from a shaly limestone three forms of trilobites, which Mr. Emmons thought probably indicated the horizon of the Potsdam group. One was identified as *Ogygia parabola* and another as Crepicephalus allied to *C. diadematus*.[2]

In the Oquirrh Mountains, at Ophir City, Utah, the section discloses a thickness of about 400 feet of compact reddish white Cambrian quartzite, above which are about 100 feet of greenish yellow clay slate, in which numerous trilobites and primordial fossils occur.[3]

In the Schell Creek Mountains of Nevada there are limestones in which primordial fossils have been found overlying heavy bodies of quartzite. Among the organic remains of this range two species have been identified: *Crepicephalus* (*Loganellus*) *anytus* and *Lingulepis mæra*.[4]

At the northern end of Pogonip Ridge, of the White Pine Mountains of central Nevada, Mr. Arnold Hague mentions the presence of obscure outcrops of mica slates and black arenaceous and argillaceous slates and shales, in turn overlaid by an undetermined thickness of a compact, vitreous, steel-gray quartzite, closely resembling the Cambrian quartzites of other Nevada localities. Above this quartzite, and forming the lower beds along the greater part of the ridge, occurs the Pogonip limestone, which extends to the top of Pogonip Mountain, with a thickness of from 3,000 to 4,000 feet of strata. They dip with an angle of 24° to 30° eastward. The lower beds are a fine-grained, somewhat siliceous, black limestone, varying considerably in compactness and bedding, and frequently passing into calcareous shales. Higher up in the series, they develop more of a dark blue color, banded with layers of fine arenaceous limestones and occasional cherty bands a few inches in thickness.[5] From the lower beds of the limestone series he collected thirteen species of Upper Cambrian fossils.

Mr. Hague states that in Eureka mining district, northwest of White Pine, the section of Prospect Mountain has the same lithologic habit as that at White Pine, and carries throughout the greater part of the forma-

---

[1] Op. cit., p. 410.
[2] Op. cit., p. 377.
[3] Op. cit., p. 444.
[4] Op. cit., p. 486.
[5] Hague, Arnold, and S. F. Emmons: Descriptive Geology. U. S. Geol. Expl. of the 40th Par.; Clarence King, vol. 2, 1877, pp. 542, 543.

tion Primordial fossils, showing beyond doubt that the two series of beds are the same and equivalent to the Potsdam sandstone of Wisconsin. This statement is followed by a list of fifteen species, all of which belong to the Upper Cambrian fauna.[1]

The collections made by the officers of the Fortieth Parallel Survey were studied and reported upon by Messrs. Hall and Whitfield. Of the fauna referred to the Potsdam period they say: "Although there is not a single species common to the two regions, yet there is such a close generic resemblance as to leave no doubt whatever of the positive identity of the formations." They mention the resemblance between the fauna referred to the Potsdam zone in Texas and the Upper Mississippi Valley, Wisconsin, Minnesota, etc.[2] In speaking of the trilobites from the base of Ute Peak, Wasatch range, Utah, they state that the fauna is referred to the Quebec group on the evidence of the Brachiopodus and Molluscan fauna.[3] There must have been some confusion in relation to the occurrence of trilobites and the Molluscan fauna, as the trilobites belong to the Lower Cambrian zone, and have nothing in common with the fauna which they refer to the Quebec group.

In the comprehensive review of the geology of the fortieth parallel, Mr. Clarence King describes the Cambrian and Silurian rocks largely from the data published in the volume of Messrs. Hague and Emmons[4] and in the recapitulation of the Paleozoic he gives a condensed description of the Cambrian as known to him in Utah and Nevada. The base of the Cambrian is never seen. This is explained by the fact that the Cambrian sediments accumulated in the deep valleys between the Archean ridges, and that the lower beds have not subsequently been brought up to the surface. Under the term Cambrian he includes all of the rocks of the lowermost Paleozoic exposures up to and including the whole of the Primordial, thus following approximately the eastern nomenclature. In describing the rocks referred to the Cambrian he says:

> Thus far, among the reported occurrences of the rocks of this horizon in the Cordilleras, the locality at the mouth of Big Cottonwood Cañon must remain as the finest example and the stratigraphical type. The lowest member—the Cottonwood slates, a group about 800 feet thick, which here rest upon highly metamorphic Archean schists—has thus far yielded no organic forms. Though searched by us with considerable care, it presented no indications of life. The rocks are dark blue, dark purple, dark olive-green, and blackish argillites, all highly siliceous, and as a group sharply defined from the light-colored quartzitic schists which conformably overlie them. This second group, by far the greatest of the whole Cambrian series, is a continuous zone of schists which have a prevailing quartzitic character, though varied with considerable amount of argillaceous matter. It would seem to be the product of a fine-grained arkose formation, simply compressed into dense schists. From 8,000 to 9,000 feet thick, it has a general uniformity of lithological condition from bottom to top,

[1] Op. cit., pp. 547, 548.

[2] Hall, James, and R. P. Whitfield: Paleontology (of the 40th Parallel). General remarks. U. S. Geol. Survey of the 40th Parallel, vol. 4, 1877, pp. 199, 200.

[3] Op. cit., p. 200.

[4] Systematic Geology: U. S. Geol. Exploration of the 40th Parallel, Clarence King, geologist in charge, vol. 1, 1878, pp. 154–189.

except that in the region of Twin Peaks are some phlogopite schists and siliceous zones carrying considerable muscovite. The phlogopite members recur in the Egan Cañon region. The prevailing colors of this member are gray, greenish gray, drab, and pale brown; never dark colors. Conformably overlying it are 2,500 to 3,000 feet of cream-color and salmon- color and white quartzites and quartzo-feldsites. Occasional sheets of conglomerate are seen in the quartzites not far below the summit of the Cambrian.[1]

The details of the Cottonwood Cañon section to this point have not been quoted, as these rocks are beneath the line provisionally drawn between the Cambrian and pre-Cambrian rocks. This will be noticed under the description of the Cambrian rocks of the Rocky Mountain province. Above the quartzite series there is a thin series of green siliceous argillites which are usually not more than 75 or 80 feet thick, in which fossils of a Primordial type have been found. A description is given of the Cambrian as recognized in central Nevada, and a comparison made between it and the Cambrian of the Mississippi Valley and the Wasatch section. A complete list of the fossils of the Utah and Nevada Cambrian is given on page 231, and on page 233 a list of those from the Quebec group, eight of which are from the Middle Cambrian zone, and will be mentioned under the description of the Cambrian fauna of the Rocky Mountain province. The geographic distribution of the Cambrian rocks and their mode of occurrence, as shown in cross-section, is represented on the sheets of the atlas accompanying the report.

In 1882 Mr. Arnold Hague published a preliminary report on the geology of the Eureka district,[2] which was followed in 1883 by the abstract of a report on the geology of the district.[3] In this latter report a detailed description is given of the Cambrian rocks of the Prospect Mountain section. It is accompanied by a map of the district and a plate of sections showing the relation of the Cambrian rocks to the superjacent formations.

The fauna of the Cambrian rocks of the Eureka district was described and illustrated by Mr. C. D. Walcott in 1884. A short description of the range of the species is given, also a tabulation of the Paleozoic section of Central Nevada, showing the vertical range of genera.[4] This was republished in 1886 with greater detail,[5] accompanied by an original description of the Big Cottonwood Cañon section (pp. 38, 39), and a section in the Highland range, 125 miles south of the Eureka section (pp. 33–35), with notes upon the section at Pioche and Ophir City.

[1] Op. cit., pp. 229, 230.

[2] Report [on work in Eureka district]. 2d annual report U. S. Geol. Survey, 1880–'81. pp. 21–35, 1882.

[3] Hague, Arnold: Abstract of report on geology of the Eureka district, Nevada. U. S. Geol. Surv., 3d annual report, 1881, 1882, pp. 237–290, 1883.

[4] Paleontology of the Eureka district. U. S. Geol. Survey, Monograph vol. 8, 1884.

[5] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, 1886, pp. 30–33.

IDAHO.

In a letter to Prof J. D. Dana, dated Fort Hall, Idaho, July 7, 1872, Prof. F. H. Bradley wrote to announce the discovery of the Quebec group. In a limestone he found many trilobites, some gasteropods and brachiopods, and beneath the limestone a compact ferruginous quartzite, which from its position he considered as representing the Potsdam sandstone.[1] Near Malade City he discovered a series of limestones containing Conocoryphe, Bathyurus, Dikelocephalus, Agnostus, etc. He states in a later report that—

> The first examination of these Malade rocks was made at a point where the section terminated below in a very quartzitic sandstone, which occupied the relative position of the Potsdam, and was accordingly referred with doubt to that group in a letter extract which was published in the August number of the American Journal of Science. Later examinations have shown that this was really a part of the true Quebec, whose base is not here exposed.[2]

The fossils collected by Prof. Bradley were studied by Mr. F. B. Meek, who identified the genera Agnostus, Conocoryphe, etc., along with several genera of the Lower Silurian fauna, and gave Prof. Bradley the paleontologic data for his correlation.[3]

It is to be borne in mind that at the time of the work referred to, the Quebec group was made to cover the horizons of the Potsdam, Calciferous, and Chazy of the New York section. Again, throughout the writings of Messrs. Hayden, Bradley, and Meek there are found many references to the Quebec group, of strata that belong to different formations. This confusion arose primarily from the misinterpretation of the mode of occurrence of the Upper Cambrian and Lower Silurian faunas at Point Levis, Canada, the typical locality of the Quebec group.

The Cambrian rocks north of Malade City were studied by Dr. A. C. Peale in 1877, in the Portneuf and Bannock ranges. He also visited the Bear River range. Several carefully measured sections are published with a summary of the rocks referred to the Silurian that will be referred to in the description of the rocks of Idaho.[4]

The northern end of the Portneuf range, in the vicinity of Mount Putnam, came within the Teton district of Prof. Orestes St. John. The central portion of the mountain is formed of ancient quartzite, alternating with slaty micaceous shale, which alternates with limestones above; and on the northern terminus of Mount Putnam there is an exhibition of the full series of the Paleozoic formations as developed in this region.[5]

---

[1] On the discovery of the Quebec formation in Idaho. Am. Jour. Sci., 3d ser., vol. 4, 1872, p. 133.

[2] Bradley, Frank H.: Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 201.

[3] Preliminary paleontological report, * * * with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Territories, embracing portions of Montana, Idaho, Wyoming, and Utah. 6th Ann. Rep., 1873, pp. 431, 432.

[4] Report on the geology of the Green River district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 567–572, 599, 613–616.

[5] Report of the geological field work of the Teton division. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 477–484.

On the map accompanying the twelfth annual report of the Hayden survey, issued in 1883, the geographic distribu tion of the strata referred to the Silurian (which includes the Cambrian and the quartzite referred to the Potsdam and a portion of the limestones referred to the Quebec) is delineated as it occurs in southeastern Idaho. This is based on the work of Messrs. Bradley, Endlich, St. John, and Peale, of the Hayden survey.

MONTANA.

During the field season of 1872 Dr. F. V. Hayden made a geologic reconnaissance of certain portions of Montana and noted the presence of limestone on the Gallatin River, above Gallatin City, that contained numerous fossils. The thickness of the entire series of strata referred to the Lower Silurian is estimated at 1,600 feet. The massive limestones referred to the Potsdam group are about 400 feet thick and pass gradually down into 50 feet of thinly laminated, cherty limestones or calcareous mud layers, with abundant organic remains. These are separated by a purplish sa ndstone that rests upon variegated shaly clays, yellow, green, etc., then hard, dull purplish brown quartzose sandstones, which in turn are underlaid by alternating sandstones and clays, the whole having a thickness of over 1,000 feet.[1]

The fossils collected were studied by Mr. F. B. Meek, who identified the genera Lingulepis, Conocoryphe, Bathyurus, Acrotreta, Hyolithes, and Agnostus from the beds of the east side of the Gallatin River.[2]

Strata of "Primordial age" were discovered by Messrs. Dana and Grinnell upon the southwestern slope of Little Belt Mountains and the south extremity of the Belt range of mountains; these are referred to with certainty, owing to the finding of Primordial fossils.[3]

In 1884 Dr. F. V. Hayden revisited the Gallatin River locality, in company with Dr. A. C. Peale.[4] The section near the mouth of the East Gallatin River was studied in detail by Dr. Peale and two lithologically well defined groups determined.

In the report of the following year the East Gallatin group is spoken of as probably Middle Cambrian.[5]

In his administrative report to the Director of the U. S. Geological Survey for the field season of 1889, Dr. A. C. Peale tabulates the Gallatin River Paleozoic section, and includes under the Cambrian the Gallatin limestone, 835 feet in thickness, and the Gallatin sandstone, 415 feet. Beneath the Gallatin limestones are 5,000 feet of conglomer-

[1] Report of F. V. Hayden, U. S. Geol. Sur. of the Terr., 6th Ann. Rep., 1873. p. 72.

[2] Preliminary paleontological report, . . . with remarks on the ages of the rocks, etc. U. S. Geol. Sur. of the Territories, embracing portions of Montana, Idaho, Wyoming, and Utah; 6th Ann. Rep., 1873 pp., 431, 432.

[3] Geological report. Report of a geological reconnoissance from Carroll, Montana Terrritory, on the Upper Missouri, to the Yellowstone Park and return, made in the summer of 1875, by Wm. Ludlow: 1876, p. 22.

[4] Administrative Report Montana Division. U. S. Geol. Survey, 6th Ann. Rep., 1884-'85, 1885, pp. 49-51.

[5] *Ibid.*, U. S. Geol. Survey, 7th Ann. Rep. for 1885-'86, 1888, p. 86.

itic micaceous sandstones, with bands of siliceous limestones and indurated clay shales, which he refers to the Algonkian.[1]

CANADIAN EXTENSION.

The discovery of rocks of Cambrian age in the western portion of British Columbia is of recent date. During the summer of 1883 Dr. G. M. Dawson and Mr. R. G. McConnell investigated the Paleozoic rocks on the line of the Canadian Pacific Railroad and discovered at the Crow Nest Pass a great thickness of limestone of Devonian age, beneath which is a great series of slaty and quartzite rocks. No fossils were found in the beds, but some were found in detached fragments, which are referred to the Cambrian.[2] In the report published in 1886 Dr. G. M. Dawson says that of the rocks referred to throughout his report as Cambrian no complete general section can be offered. Along the line of the Columbia Valley the basal beds were not observed. The component beds of the great Cambrian series are, in the main, quartzites and quartzitic shales, passing into argillites, occasionally including limestones or more or less calcareous or dolomitic materials and conglomerates.[3]

Near Waterton Lake a section was measured 3,000 feet in thickness; another at South Kootanie Pass had a minimum (estimated) thickness of the outcropping Cambrian beds of 11,000 feet, and it included neither the summit nor the base of the series. Other sections were measured, but none were found in which the whole volume of the formation could be ascertained.[4]

Dr. Dawson compares these sections with that of the Wasatch Mountains of Utah; and more recent discoveries have shown that they are quite similar in character. If the view of separating the pre Olenellus beds from the Cambrian is accepted, most of the South Kootanie Pass rocks will be referred to the Algonkian, corresponding in this respect to the Algonkian (?) of the Big Cottonwood section of the Wasatch Mountains, Utah.

Dr. Dawson further states that Mr. H. H. Winwood announced the discovery of Cambrian fossils in the Kicking Horse Pass in a letter to the Geological Magazine in 1885.[5] From among the specimens obtained at that time Mr. C. D. Walcott recognized *Olenellus howelli* and *Olenoides levis*, trilobites characteristic of the Prospect Mountain group of Nevada.[6] Numerous other references occur in Dr. Dawson's report in connection with the description of the local details of the

[1] Administrative Report, Montana Division. U. S. Geol. Surv., 10th Ann. Rep., 1890, p. 131.

[2] Dawson, Geo. M.: Recent geological observations on the Canadian Northwest Territory. Science, vol. 3, 1884 p. 648.

[3] Preliminary report on the physical and geological feature of that portion of the Rocky Mountains between lat. 49° and 51° 30′. Geol. Survey Canada, new ser., vol. 1, 1886, p. 157B.

[4] Op. cit., p. 158B.

[5] Geological age of the Rocky Mountains. Geol. Mag., new ser., dec. 3, vol. 2, 1885, p. 240.

[6] Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30′. Geol. Surv. Canada, new ser., vol. 1, 1886, p. 140B.

geology. One of these refers to the finding of a specimen of *Ptychoparia oweni* M. and H. on the Cascade River in débris brought down from the mountain, indicating the presence of the Cambrian in the Cascade Mountains.[1]

An admirable map accompanies Dr. Dawson's report, and includes the region between latitude 49° and 50° 30′. The geographic distribution of the Cambrian quartzite series and its relations to the superjacent Carboniferous and Devonian rocks is delineated, and their stratigraphic position is shown in an accompanying diagrammatic section.

When exploring the Yukon district in 1887 Dr. Dawson[2] discovered that the country north of Dease Lake had a granitic nucleus with Paleozoic rocks on its flanks, ranging from the Cambrian to the Carboniferous. No details are given.

The detailed exploration of the Paleozoic rocks west of the great Archean area, near the border of British Columbia and Alberta, was undertaken by Mr. R. G. McConnell, and his results are presented in the annual report of the Canadian Survey for 1886. The Castle Mountain group, a great limestone formation, has a known minimum thickness of 7,700 feet. The lower portion is of Cambrian age, and the upper part forms the base of the Lower Silurian (Ordovician). Beneath the Castle Mountain group the Bow River series forms a great thickness of dark colored argillites, associated with some sandstones, quartzites, and conglomerates. The portion exposed has an estimated thickness of 10,000 feet, and in the upper part of it occur the fossils mentioned by Dr. Dawson, *Olenellus gilberti*, etc.[3] The occurrence of fossils of Cambrian age in the lower portion of the Castle Mountain group is noted on page 28D of the report.

The fauna from the slates or shales at the base of the Castle Mountain group, in the Mount Stephen section, was described by Dr. C. Rominger in 1887,[4] and reviewed by Mr. C. D. Walcott in the following year.[5]

In noticing the two papers just mentioned Mr. R. G. McConnell gives a résumé of the section at Mount Stephen. He states that no fossils have been detected in the lower part of the Bow River series, but specimens of *Olenellus gilberti* were found by Dr. Dawson in 1884 about 2,000 feet below the top of the formation. The next fossiliferous zone occurs near the junction of Bow River and Castle Mountain groups, where Paradoxides was found; and a third zone, between 3,000 and 4,000 feet higher up, carries the fauna described by Dr. Rominger.[6]

---

[1] Op. cit., p. 143B.

[2] Notes on exploration in Yukon District. Science, vol. 10, 1887, p. 165.

[3] Report on the Geological Structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, Ann. Report, new ser., vol. 2, 1887, pp. 24–30 D.

[4] Description of Primordial fossils from Mount Stephens, Northwest Territory of Canada. Phila. Acad. Sci. Proc., 1888, pp. 12-19, Pl. I.

[5] Cambrian fossils from Mount Stephens. Am. Jour. Sci., 3d ser., vol. 36, 1888, pp. 161–166.

[6] Notes on the geology of Mount Stephen, British Columbia. American Geologist, vol. 3, 1889, pp. 23–25.

In a "Note on the geology of the Selkirk Range," of British Columbia, Dr. George M. Dawson states that the Olenellus fauna has been found 3,000 feet down in the Bow River series.[1] He refers the Nisconlith, and the lower 15,000 feet of the Selkirk series, of the Selkirk section, to the Cambrian, and correlates them with the Bow River and lower portion of the Castle Mountain series of the western side of the Rocky Mountains. (The details of these series are given in chapter IV, of this paper.)

PALEONTOLOGY.

The first description of Cambrian fossils from the Rocky Mountain province is that by Mr. F. B. Meek, in 1868, who described from the material discovered by Mr. Clayton at Silver Peak, Nevada, *Ethmophyllum whitneyi* and *E. gracile*.[2] Shortly after he changed the reference of these species to Archæocyathus, making *A. whitneyi* and *A. gracile*.[3] In 1870 he added *Paradoxides? nevadensis* and *Conocoryphe* (*Conocephalites*) *kingi*, from Antelope Spring, Nevada. From the known position of the genus Conocephalites the two species were referred by him to the Primordial zone.[4]

In 1872 Prof. J. D. Whitney calls attention to the occurrence of the Primordial fauna near Eureka, Nevada, at a locality discovered by Mr. J. E. Clayton. He identified a species closely related to *Agraulos oweni* of Meek and Hayden, and fragments of the genera Conocoryphe, Paradoxides, Lingulepis, and Obolella.[5] A notice of this discovery was also published in the proceedings of the California Academy of Sciences in the same year. (Vol. 4, p. 200.)

From the Upper Cambrian rocks of southeastern Idaho and southern Montana, Mr. F. B. Meek described in 1873 *Iphidea?? sculptilis* (p. 479), *Agnostus bidens* (p. 463), *Conocoryphe* (*Conocephalites*) *gallatinensis* (p. 485), *Bathyurus? haydeni* (p. 482), *B. serratus* (p. 480), *Bathyurellus* (*Asaphiscus*) *bradleyi* (p. 484), *Bathyuriscus whecleri* (p. 485, foot-note). It is stated on page 465 that *Bathyuriscus* (*Dikelocephalus?*) *truncatus* is described in the report. It does not, however, appear in the text. He also identified the species *Acrotreta subconica* Kutorga (*A. attenuata* proposed if it proved to be a distinct species, p. 463), *Hyolithes gregaria* M. & H., *Camerella calcifera* Billings, and *Agnostus josepha*, Hall. Numerous generic references are made from the fragments in the collection, and in the lists from various localities species of the Calciferous zone of the Lower Silurian (Ordovician) occur, especially in the list of the collection from Malade City.[6]

[1] Bull. Geol. Soc. America, vol. 2, 1891, p. 171.

[2] Preliminary notice of a remarkable new genus of Corals, probably typical of a new family, * * * from the Silurian rocks of Nevada Territory. Am. Jour. Sci., 2d ser., vol. 45, 1868, pp. 62–64.

[3] Note on Ethmophyllum and Archæocyathus. Am. Jour. Sci., 2d ser., vol. 46, 1868, p. 144.

[4] Meek, F. B.: Descriptions of fossils collected by the U. S. Geological Survey, under the charge of Clarence King, esq. Phil. Acad. Sci. Proc., vol. 22, 1870, pp. 62–64.

[5] Note on the occurrence of the "Primordial Fauna" in Nevada. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 84, 85.

[6] Preliminary paleontological report, * * * with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., embracing portions of Montana, Idaho, Wyoming, and Utah; 6th Annual Report, 1873, *pp. 463–487.*

From the collections made by the geologists of the Wheeler survey west of the one hundredth meridian, Dr. C. A. White describes, in a preliminary report, *Cruziana linnarssoni*, *C. rustica*, *Acrotreta? subsidua*, *Trematis pannulus*, and *Agnostus interstricta*. He also identified *Hyolithes primordialis* Hall *?*; and published the manuscript description by Mr. Meek of *Olenellus gilberti* and *O. howelli*.[1] From the strata referred to the age of the Quebec group he describes *Acrotreta pyxidicula* (p. 9) and *Dikelocephalus flagricaudus* (p. 12). The former species was subsequently identified by Mr. C. D. Walcott as *Acrotreta gemma* of the Upper Cambrian, and the latter species is referred to the Middle Cambrian fauna as *Zacanthoides flagricaudus*. The manuscript descriptions of *Olenellus gilberti* and *O. howelli* by Mr. Meek were also printed in 1875 under the names of *Olenus* (*Olenellus*) *gilberti* and *O.* (*O.*) *howelli* in the report of Mr. G. K. Gilbert.[2]

The species described by Dr. White in his preliminary report of 1874 were redescribed and illustrated by him in 1875. In addition to the species mentioned in the preliminary report he describes and illustrates *Concoryphe* (*Ptychoparia*) *kingi* Meek (p. 40) and *Asaphiscus wheeleri* Meek (p. 43.)[3]

The two species described by Mr. Meek from Antelope Spring, Utah, in 1870, were redescribed and illustrated by him in 1877, under the names of *Conocoryphe* (*Ptychoparia*) *kingi* and *Paradoxides? nevadensis*. In the description of the latter species he gave reasons for believing that the generic reference was incorrect, and that the species belonged to an undescribed genus. For this genus, if the species proved not to be Paradoxides, he proposed the genus Olenoides.[4]

The description of the collections of the Fortieth Parallel Survey by Messrs. Hall and Whitfield added a large number of new forms to the Middle Cambrian fauna.[5]

The new species described are:

Obolella discoidea, p. 205.
Linguleps mæra, p. 206.
? minuta, p. 206.
Kutorgina minutissima, p. 207.
Leptæna melita, p. 208.
Crepicephalus (Loganellus) hagnei, p. 210.
(Loganellus) nitidus, p. 212.
(Loganellus) granulosus, p. 214.
(Loganellus) maculosus, p. 215.

[1] Preliminary report upon invertebrate fossils collected by the expeditions of 1871, 1872, and 1873, with descriptions of new species, pp. 27. Geog. and Geol. Sur. west of 100th Mer., Lieut. Wheeler in charge, Washington, 1874, pp. 4–12.

[2] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Sur. west of 100th Mer., vol. 3, Geology, 1875, pp. 182, 183.

[3] Report upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico, and Arizona by parties of the expeditions of 1871–74. Wheeler's Expl. and Sur. west of the 100th Mer., vol. 4, pt. 1, 1875.

[4] U. S. Geol. Expl. of the 40th Parallel, vol. 4, pt. 1, 1877, pp. 20–25.

[5] *Ibid.*, vol. 4, 1877, pt. 2, pp. 205–246.

Crepicephalus (Loganellus) unisulcatus, p. 216.
(Loganellus) simulator, p. 218.
(Loganellus) anytus, p. 219.
(Bathyurus) ? angulatus, p. 220.
Conocephalites (Pterocephalus) laticeps, p. 221.
Ptychaspis pustulosa, p. 223.
Chariocephalus tumifrons, p. 224.
Dikelocephalus bilobatus, p. 226.
multicinctus, p. 226.
flabellifer, p, 227.
Agnostus communis, p. 228.
neon, p. 229.
prolongus, p. 230.
tumidosus, p. 231.
Lingulepsis ella, p. 232.
Conocephalites subcoronatus, p. 237.
Crepicephalus ? (Loganellus) quadrans, p. 238.
Dikelocephalus quadriceps, p. 240.
wasatchensis, p. 241.
? gothicus, p. 242.
Ogygia producta, p. 244.
parabola, p. 245.

Of these species those from *Lingulepsis ella* to *Ogygia parabola*, inclusive, are referred to the Quebec group, and the others to the Potsdam. The descriptions are accompanied by fine illustrations of all the species mentioned.

In 1880 Dr. C. A. White referred his *Acrotreta ? subsidua*, described in 1874, to the genus Acrothele of Angelin.[1]

The study of a collection made by the U. S. Geological Survey from the Eureka district, Nevada, gave Mr. C. D. Walcott material for the description of a number of new species from the Cambrian. They include the following:[2]

Acrothele ? dichotoma, p. 14.
Scenella ? conula, p. 15.
Kutorgina whitfieldi, p. 18.
prospectensis, p. 19.
Orthis eurekensis, p. 22.
Stenotheca elongata, p. 23.
Agnostus richmondensis, p. 24.
seclusus, p. 25.
Olenellus iddingsi, p. 28.
Dikelocephalus nasutus, p. 40.
richmondensis, p. 41.
? angustifrons, p. 42.
iole, p. 43.
marica, p. 44.
? expansus, p. 45.
Ptychoparia (?) prospectensis, p. 46.
(?) linnarssoni, p. 47.

[1] Note on Acrothele. U. S. Nat. Mus. Proc., vol. 3, 1880, p. 47.
[2] Paleontology of the Eureka district. U. S. Geol. Surv., Monograph, vol. 8, 1884, pp. 11-64.

Ptychoparia (?) (Solenopleura) (?) breviceps, p. 49.
(?) pernasutus, p. 49.
(Euloma?) dissimilis p. 51.
occidentalis, p 51.
similis, p. 52.
similis, var. robustus, p. 53.
(Euloma?) affinis, p. 54.
læviceps, p. 54.
(Pterocephalus) occidens, p. 58.
Anomocare? parvum, p. 59.
Agraulos? globosus, p. 61.
Arethusina americana, p. 62.
Ogygia? spinosa, p. 63.
(?) problematica, p. 63.

The following genera and species are mentioned and illustrated:

Protospongia fenestrata, p. 11.
Lingulepis mera, p. 12.
? minuta, p. 13.
Lingula? manticula, p. 13.
Obolella discoidea, H. & W., p. 14.
Acrotreta gemma, Billings, p. 17.
Under this species are also included *Acrotreta subconica* and *A. attenuata*, Meek, 1873, and *Acrotreta pyxidicula*, White, 1874.
Kutorgina sculptilis, Meek, p. 20.
The synonymy of this species includes *Iphidea* (?) *sculptilis*, 1873, and *Kutorgina minutissima*, H. & W., 1877.
Leptæna molita, H. & W., p. 22.
Hyolithes primordialis, Hall, p. 23.
Agnostus bidens, Meek, p. 26.
communis, H. & W., p. 27.
neon, H. & W., p. 27.
prolongus, H. & W., p. 28.
Olenellus gilberti, Meek, p. 29.
howelli, Meek, p. 30.
Dikelocephalus bilobatus, H. & W., p. 40.
osceola, Hall, p. 40.
? quadriceps, H. & W., p. 45.
Ptychoparia oweni, M. & H., p. 55.
Under this species are placed as synonyms *Conocoryphe* (*Ptychoparia*) *gallatinensis*, Meek, 1873, *Crepicephalus* (*Loganellus*) *centralis*, Whitfield, 1877.
anytus, H. & W., p. 56.
granulosus, P. haguei and P. nitidus, H. & W., p. 57.
Under the latter species *Crepicephalus* (*Loganellus*) *simulator*, H. & W., 1877, is placed as a synonym.
unisulcatus, H. & W., p. 38.
(Pterocephalus) laticeps, H. & W., p. 59.
Ptychaspis minuta, Whitfield (?) p. 60.
Chariocephalus (?) tumifrons, H. & W., p. 61.

Notes on the genus Acrotreta of Kutorga are given on page 16; and observations on *Olenellus howelli* on pages 32–39.

In 1886 Mr. C. D. Walcott reviewed the species which he then considered to belong to the Olenellus, or Middle Cambrian fauna.[1]

The following new species were described from Utah and Nevada:

Eocystites ? longidactylus, p. 94.
Orthis ? highlandensis, p. 119.
Hyolithes billingsi, p. 134.
Leperditia ? argenta, p. 146.
Olenoides typicalis, p. 183.
levis, p. 187.
Ptychoparia housensis, p. 201.
piochensis, p. 201.
Crepicephalus liliana, p. 207.
augusta, p. 208.
Orytocephalus, new genus, p. 210.
Orytocephalus primus, p. 210.
Bathyuriscus howelli, p. 216.

The genus Ethmophyllum, described by Mr. Meek in 1868, and the species placed under it referred in the same year to Archæocyathus, is redefined as the genus Ethmophyllum, with *Ethmophyllum whitneyi* as the type (p. 81.) *Ethmophyllum gracile* Meek is placed as a synonym of the latter species. Descriptions and illustrations of the following species also appear in this work:

Protospongia fenestrata, Salter, p. 90.
Lingulella ella, H. & W. p. 97.
Acrotreta gemma, Billings, p. 98.
Kutorgina pannula, White, p. 105.
prospectensis, Walcott, p. 106.
Acrothele subsidua, White, p. 108.
Scenella ? conula, Walcott, p. 127.
Stenotheca ? elongata, Walcott, p. 129.
Agnostus interstrictus, White, p. 149.
Olenellus iddingsi, Walcott, p. 170.
gilberti, Meek, p. 170.
Olenoides nevadensis, Meek, p. 181.
spinosus, Walcott, p. 184.
? flagricaudus, White, p. 185.
quadriceps, H. & W., p. 187.
wasatchensis, H. & W., p. 189.
Ptychoparia kingi, Meek (sp.), p. 193.
quadrans, H. & W., p. 199.
? prospectensis, Walcott, p. 202.
subcoronata, H. & W., p. 205.
Anomocare ? parvum, Walcott, p. 209.
Bathyuriscus productus, H. & W., p. 217.
Asaphiscus wheeleri, Meek, p. 220.

A discussion of several of the genera is also presented.

In a paper on the stratigraphic position of the Olenellus fauna Mr. C. D. Walcott reviewed the stratigraphic position of the fauna described in Bulletin 30 of the U. S. Geological Survey, and referred the

[1] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886.

following species, formerly assigned to the Lower Cambrian fauna, to the Middle Cambrian zone, considering the Olenellus zone to include only the Lower Cambrian fauna.[1] The species are:

Protospongia fenestrata, Salter.
Eocystites ? ? longidactylus, Walcott.
Leperditia argenta, Walcott.
Agnostus interstrictus, White.
Olenoides nevadensis, Meek (sp.).
quadriceps, Hall & Whitfield (sp.).
wasatchensis, H. & W. (sp.).
spinosus, Walcott.
typicalis, Walcott.
Ptychoparia housensis, Walcott.
kingi, Meek (sp.).
piochensis, Walcott.
? prospectensis, Walcott.
quadrans, H. & W. (sp.).
subcoronata, H. & W. (sp.).
Bathyuriscus howelli, Walcott.
productus, H. & W. (sp.).
Asaphiscus wheeleri, Meek.

Ptychaspis piochensis occurs 100 feet above the Olenellus zone proper, in the Highland range section, but as it also occurs 1,137 feet higher up in the same section, it is now referred to the Middle Cambrian fauna and not to the Olenellus fauna.[2]

The presence of Cambrian fossils at Kicking Horse Pass of the Rocky Mountain division of the Canadian Pacific Railway was announced by Mr. H. H. Winwood in 1885.[3] Indirect reference was also made to this by Dr. G. M. Dawson in 1884.[4] The specimens obtained at that time were examined by Mr. C. D. Walcott, who recognized *Olenellus howelli* and *Olenoides levis*, trilobites characteristic of the Prospect Mountain group of Nevada.[5]

During the survey by Mr. R. G. McConnell of the section along the line of the Canadian Pacific Railway there was discovered at Mount Stephen a zone of fossiliferous slate 2,000 feet above the base of the Castle Mountain limestone. From the collections obtained Dr. C. Rominger described the new genus Emboliмus and five new species of trilobites, viz: *Oggygia klotzi*, *O. serrata*, *Emboliмus spinosa*, *E. rotundata*, and *Conocephalites cordilleræ*. He also identified *Menocephalus salteri ?*, Billings, *Bathyurus ?*, *Agnostus* ("compare *A. interger* Barr"), and the genera Orthis, Obolella, Kutorgina, Leptæna ?, Metoptoma, and Hyolithes.[6]

[1] Stratigraphic succession of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, pp. 374–392; vol. 38, 1889, pp. 29–42.

[2] Op. cit., p. 387.

[3] Geological age of the Rocky Mountains. Geol. Magazine, new ser., dec. 3, vol. 2, 1885, p. 240.

[4] Recent geological observations on the Canadian Northwest Territory. Science, vol. 3, 1884, p. 648.

[5] Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 51° 30′. Geol. Surv. Canada, new ser., vol. 1, 1885, p. 140B.

[6] Description of Primordial fossils from Mount Stephen, Northwest Territory of Canada. Philadelphia Acad. Sci., Proc., 1887, pp. 12–19.

A review of Dr. Rominger's work on the Mount Stephen fossils by Mr. C. D. Walcott resulted in his determining that *Embolimus spinosa*, Rom.= *Zacanthoides spinosus*, Walcott; *Embolimus rotundata*, Rom.=*Bathyuriscus howelli*, Walcott; *Ogygia serrata*=*Olenoides nevadensis*, Meek; and that *Conocephalites cordilleræ*, Rom.=*Ptychoparia cordilleræ*, Rom. (sp.), and *Ogygia ? ? klotzi*, Rom., are new to the previously known Cambrian fauna. The genus Zacanthoides is proposed to include *Olenoides typicalis*, *O. spinosus*, *O. levis*, and *O. flagricaudus*, described in 1886. There were also identified from the material studied by Dr. Rominger *Agnostus interstrictus*, *Acrotreta gemma*, *Kutorgina prospectensis*, and *Hyolithellus micans*.[1] Subsequently from the collection studied by Dr. Rominger there were described by Mr. Walcott, *Lingulella macconelli* *Crania ? columbiana*, *Acrotreta gemma* var. *depressa*, *Orthisina alberta*, *Platyceras romingeri*, *Karlia stephenensis*, *Bathyuriscus* (*Kootenia*) *dawsoni*, and the genus Ogygopsis was proposed to include the *Ogygia klotzi* of Rominger. *Linnarssonia sagittalis* was also identified.[2]

In 1890 Mr. C. D. Walcott[3] described three new species from the Highland range section of Central Nevada, referring them to the Upper Cambrian. These species are *Hyolithes attenuatus*, *H. curvatus*, and *H.* (?) *corrugatus*.

INTERIOR CONTINENTAL PROVINCE.

This province includes the Upper Mississippi area, the eastern border or Adirondack subprovince, the western border or Rocky Mountain subprovince, and the Llano County area of central Texas and the Grand Cañon of Arizona as a minor southwestern subprovince.

UPPER MISSISSIPPI AREA.

For convenience of reference the review of the literature pertaining to Wisconsin, Minnesota, and Iowa is assembled for each State. The Ozark area of southeastern Missouri is considered separately, and the Lake Superior sandstones and the controversy in relation to them is noticed under a distinct heading, after the description of the recognized Upper Cambrian rocks of Wisconsin, Iowa, and Minnesota, and their extension into Canada. This division also includes the references to the Cambrian rocks of Michigan.

WISCONSIN.

In 1843, in notes on the geology of the Western States, Dr. D. D. Owen called attention to the presence of a sandstone on the Mississippi River, at Prairie du Chien, visible beneath the Lower Magnesian lime-

[1] Cambrian fossils from Mount Stephens. Am. Jour. Sci., 3d ser., vol. 36, 1888, p. 165.

[2] Descriptions of new genera and species of fossils from the Middle Cambrian. U. S. National Museum, Proc., vol. 11, 1889, pp. 441-446.

[3] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267-276.

stone of the Wisconsin River.[1] Five years later, in the report of a geological reconnaissance of the Chippewa land district of Wisconsin, he describes with considerable detail Formation 1, or the lower sandstone of the Upper Mississippi. The formation, as a whole, is subdivided into five parts. The lowest part rests upon crystalline and metamorphic rocks, in the eastern part of the Chippewa land district, as a coarse sandstone overlaid by a still coarser quartzose sandstone.[2] At the Falls of the St. Croix the schistose, silico-calcareous layers of the second division are highly fossiliferous. In the third division the prevailing genera are Lingula and Orbicula[3] and it is designated as the "Lingula sandstone." In speaking of the beds of sandstone beneath the fossiliferous layers at Mountain Island it is stated that in all probability this is the western equivalent of the Lingula beds of the New York Potsdam sandstone.[4]

A notice of the discovery of the fauna in the lower sandstone of Wisconsin was communicated by Dr. Owen in 1848 to the Geological Society of France through a letter to M. de Verneuil.[5]

In a letter descriptive of the geology of southeastern Wisconsin addressed to Mr. J. W. Foster, Mr. I. A. Lapham states that—

> The *Inferior*, or *Potsdam sandstone*, is found at Janesville and above, occupying the bed of the river. The grains are rounded, smooth, and without apparent cement; the rock easily crumbles upon exposure; color white or red. The white variety might be used for the manufacture of glass. The discovery, in 1849, of that singular and characteristic fossil described by Mr. Hall as *Scolithus linearis* (New York Pal., vol. 1, p. 2) in this rock, in Sauk County, may be considered as settling the question of the identity of this rock with the Potsdam sandstone of the New York reports. It occupies much of the counties Marquette and Columbia, enters Dane County, and is seen in the banks of Rock River from Lake Koshkonong to Janesville.
>
> * * * II. *Calciferous rock of Eaton.*—Resting immediately upon the sandstone, at Janesville, is a limestone with grains of the same sand intermixed, giving it the form and appearance of an oolite limestone; the amount of sand diminishing as you rise from the surface of the sandstone. It accords exactly with the description given of a portion of the calciferous sandstone of New York, and contains the same fucoid (*Palæophycus tubularis*), as well as other characteristic fossils. Its character and relative position also clearly show that it is the same rock that, farther west and north, is called the *Lower Magnesian limestone*, by Drs. Owen and Locke.[6]

In the same report, Mr. Charles Whittlesey describes the sandstone as it occurs near Wolf River, etc., stating it to be a sandstone easily crushed between the fingers, which has been so extensively denuded that it is only here and there that a trace of its former existence is

---

[1] On the geology of the Western States. Am. Jour. Sci., vol. 45, 1843, p. 164.

[2] Owen, David Dale: Report of a geological reconnaissance of the Chippewa land district of Wisconsin, and incidentally of a portion of * * * Iowa and of the Minnesota territory. Letter of the Secretary of the Treasury communicating a report of a geological reconnaissance of the Chippewa land district of Wisconsin, etc., by D. D. Owen, Thirtieth Congress, first session, Senate Ex. Doc. No. 57, 1848, p. 13.

[3] Op. cit., p. 14.

[4] Op. cit., p. 15.

[5] Letter on geology of Wisconsin Territory. Bull. Soc. géol. France, 2e sér., vol. 5, 1848, pp. 294-296.

[6] Lapham, I. A.: "On the geology of the southeastern portion of the State of Wisconsin, being the *part not* surveyed by United States geologists." Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, p. 109.

left.[1] On the Upper Menomonee River the sandstone has a thickness of 150 feet, and the entire thickness is estimated at 200 feet.[2]

In giving an account of his investigations in connection with the geological survey under the direction of Messrs. Foster and Whitney, Prof. J. Hall states:

I have also satisfied myself that the sandstones of the Upper Mississippi are of the same age as the Potsdam sandstones, and that the Lower Magnesian limestone of the Western geologists is identical with the calciferous sandstone of New York, the next member of the series above the Potsdam sandstone. The thin bed of sandstone succeeding this rock can not be identified as the Potsdam sandstone by itself, but must be regarded as a repetition of the arenaceous deposits below, which likewise alternate with the calciferous sandstone near its base.[3]

He thus corroborates the view of Dr. D. D. Owen that the lower sandstone of Wisconsin is the equivalent of the New York Potsdam.

In 1851 M. E. Desor called attention to the presence at St. Croix of a fossiliferous sandstone 800 feet beneath that described by Professor Hall, in which he found fossils.[4]

In a paper on the paleontology of the lowest sandstone of the northwest Dr. D. D. Owen states that he observed multitudes of Lingulas and Orbiculas disseminated in strata abutting against the southwest side of the trap range that crosses the St. Croix River at the falls. This was in 1847. During the remainder of this season and in that of 1848 he found finer-grained and more laminated soft sandstones, with subordinated silico-calcareous layers, charged with Obolus, like those which characterize the lowest sandstones of Russia. This was in a section on the Mississippi, between the Falls of St. Anthony and the mouth of the Wisconsin River. From the results of these observations he finally developed beneath the Lower Magnesian limestone at least six different trilobite beds, separated by from 10 to 150 feet of intervening strata.[5]

In the final report on the geology of the Upper Mississippi Valley, the same writer describes the lower sandstone as composed of light-colored quartzose sandstone that forms the greater part of the formation, with intercalations of magnesian limestone, especially toward its upper part, where it graduates into Formation No. 2, and at certain localities argillaceous, and other beds of a mixed character form a considerable portion of its lower mass.[6] In a table of the elementary stratification of the lowest Protozoic sandstones he places the Lake Superior ferrugi-

[1] Remarks upon the section from the falls of Wolf River, through Navarino to Lake Michigan. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, p. 174.

[2] Whittlesey, Charles: The dip, bearing, and thickness of the Silurian groups. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, part 2, 1851, p. 183.

[3] (Geological investigations on Drummond's Island and the north shores of Lakes Huron and Michigan, etc.) Am. Acad. Proc., vol. 2, 1851, p. 254.

[4] [Potsdam sandstone on the river St. Croix.] Boston Soc. Nat. Hist. Proc., vol. 3, 1851, p. 202.

[5] On the paleontology of the lowest sandstones of the Northwest. Am. Assoc. Proc., vol. 5, 1851, pp. 169–172.

[6] Geol. Surv. of Wisconsin, Iowa, and Minnesota., and incidentally of a portion of Nebraska Territory, Philadelphia, 1852, p. 48.

nous and argillaceous sandstones, shales, and conglomerates at the base, assigning it a thickness of 5,000 feet. Above this occur coarse grits and sandstones of the Chippewa, Black and Wisconsin Rivers.[1] The placing of the lower sandstone of Lake Superior in this position is theoretical. Above the coarse sandstone the formation is divided into six trilobite beds, as follows:[2]

Table of the elementary stratification of the lowest Protozoic sandstones.—Formation 1.

			Feet.
f.	Sixth Trilobite bed...	Quartzose, light-colored sandstones of various degrees of induration, with intercalations of beds of magnesian limestone, with glistening crystalline facets, and calcareo-siliceous oolite, produced by rounded grains of quartz, encased in calcareous cement, containing Eumophalus and imperfect Trilobites. Locally with a band of green earth	50 to 85
		Mammillary and botryoidal layer of white sandstone; sometimes banded with yellow	5 to 6 inches.
e.		Thick beds of soft, yellowish and brown sandstone, sometimes with botryoidal, hard, projecting concretions passing downward into fine-grained soft sandstones approaching tripoli	40 to 50
	Fifth Trilobite bed...	Ash-colored and yellowish argillo-calcareous and magnesio-calcareous beds, containing *Dikelocephalus minnesotensis.*	
		Stillwater Trilobite bed	8 to 10
		Green, red, and yellowish sandstones with thin, schistose, dolomitic intercalations	40
		Upper, brown dolomitic layers containing Orthis, Lingulas, and columns of Crinoidea as at La Grange Mountain	4
	Fourth Trilobite bed..	Alternations of yellow, laminated sandstones, with green particles disseminated	5
		Marine Mill Trilobite grit	5
		Fucoidal layers, and thin-bedded green and yellow sandstones, at their base often a band of about 6 inches of green earth used by the Indians as a pigment	30 to 40
d.		Green and red sandstones, charged with silicate of iron	5
		Loose, green sand, and soft green sandstone	15
	Third Trilobite bed...	Micaceous sandstone, containing *Dikelocephalus meniskaensis, D. granulosa,* etc	3
		Alternations of green and ferruginous sandstones	20
		Micaceous sandstones containing *D. meniskaensis,* etc	2
		Thin layers of green sand, alternating with green earth, impregnated with silicate of iron	30 to 40
		Lower, brown siliceo-calcareous and dolomitic bands of Mountain Island, and elsewhere	4
		Soft, thin-bedded sandstones, with scales of mica disseminated	10 to 15
c.		Coarse lingula grit, green, yellow, sometimes almost white	100 to 130

[1] Op. cit., p. 53.

[2] Op. cit., pp. 52, 53.

Table of the elementary stratification of the Lowest Protozoic sandstones, etc.—Continued.

			Feet.
b.	Second Trilobite bed	Fine grit. Place of the Menomonie Trilobite grit (?). White and yellow sandstone, and Obolus layers of Black River	15
	First Trilobite bed	Ferruginous Trilobite grits. Schistose sandstone, containing fork-tailed Trilobite beds and Obolus layers	1 to 8
		Magnesio-calcareous rock, with Obolus and fork-tailed Trilobite	3
		Highly fossiliferous schistose, siliceo-calcareous layers, interlaminated with argillaceous, marly beds, charged with sulphate of iron; the former full of Lingulas and Orbiculas (Falls of St. Croix)	50
a		Sandstone, with oblique lines of deposition, alternating with pebbly sandstones and coarse grits of the Chippewa and Black and Wisconsin Rivers near the falls	50 to 100
		Place of the Lake Superior ferruginous and argillaceous sandstones, shales, and conglomerates	5,000

The geographic distribution of the formation is shown on the map accompanying the report.

The local details of the sections in Wisconsin are reported upon by Prof. B. F. Shumard. Much of the information here given was used by Dr. Owen in giving the summary of the divisions referred to Formation No. 1, or the lower sandstone.[1]

The sandstones of the south shore of Lake Superior are described by Mr. J. C. Norwood, and a section given of them as seen at the mouth of Cranberry River. He also describes the sandstones of the St. Croix River.[2]

In his annual report of the geological survey of the State of Wisconsin Prof. J. G. Percival describes the lower sandstone with considerable detail, but without special addition to the information given by Dr. Owen. He separates, however, the quartz rock of the Baraboo and of Portland from the Lower sandstone.[3]

The volume of the geological survey of Wisconsin, by Prof. James Hall, contains a general account of the Potsdam sandstone. The opening paragraph describes it as follows:

> The lowest rock of the series is the Potsdam sandstone, which is known in the northwest as the Lower sandstone, in contradistinction to the Upper or St. Peter's sandstone, which lies above the Lower Magnesian limestone. This is equivalent to the Potsdam sandstone in New York, and holds in all respects the same geological position: it is the lowest fossiliferous rock observed in the geological surveys of New York, where it received its name.
>
> This rock has been traced, with slight interruptions, westward from Lake Cham-

[1] Geol. Report of local, detailed observations in the valleys of the Minnesota, Mississippi, and Wisconsin Rivers. Report of a geological survey of Wisconsin, Iowa, and Minnesota; and incidentally of a portion of Nebraska Territory. Philadelphia, 1852, pp. 475–531.

[2] Geol. Report of a survey of portions of Wisconsin, and Minnesota. Rep. Geol. Surv. of Wisconsin, Iowa, and Minnesota; and incidentally of a portion of Nebraska Territory. Philadelphia, 1852, pp. 275–277.

[3] Annual Report of the Geological Survey of the State of Wisconsin. Madison, 1858, pp. 92–101.

plain through Canada to the outlet of Lake Superior and along the south shore of that lake.[1]

This is followed by a general account of the formation and of the organic remains found in it.[2]

In the same volume Prof. J. D. Whitney prints a brief résumé of the Potsdam or lower sandstone.[3]

In a paper entitled "Preliminary notice of the fauna of the Potsdam sandstone," Prof. James Hall states that in 1850 he had the opportunity of tracing the formations from Drummond's Island and St. Mary's River to the head of Green Bay and thence across the country to the Mississippi River.[4] He comes to this conclusion:

> The position of the sandstone on the St. Mary's admitted of no doubt, and its relative position to the lower limestone had before that time been well determined, and the same was likewise ascertained by the several exploring parties along different lines between Lake Superior and Green Bay.
>
> Throughout Wisconsin there is no difficulty in recognizing the following sequence:
>
> Trenton limestone;
> Black River or Buff limestone;
> Birdseye limestone;
> St. Peter's sandstone;
> Lower Magnesian limestone, or calciferous sandstone;
> Potsdam sandstone.
>
> The St. Peter's sandstone holds the place of the Chazy limestone of the more eastern localities, and, with this exception, we have the same sequence that we find in New York, many of the fossils being common to the limestone of New York and Wisconsin.
>
> Dr. Owen, in his published report, has adopted this view of the sequence, and the explorations of subsequent years have confirmed the opinions then entertained; and I believe at this time every geologist will admit the identity of the Potsdam sandstone of New York and the Lower sandstone of the Upper Mississippi Valley.
>
> In speaking of this sandstone I shall, therefore, without hesitation, refer to it as the Potsdam sandstone.[5]

A list of fossils described in the memoir is given to illustrate their stratigraphic position.[6] In this list the fauna is divided into that of the lower beds, middle beds, and upper beds, the latter characterized especially by the presence of the genus Dikelocephalus. In a supplementary note on the Potsdam sandstone that accompanies the memoir he gives a résumé of the evidence upon which the lower sandstone of the Upper Mississippi Valley has been placed in parallelism with the sandstone of New York, known as the Potsdam sandstone, as follows:[7]

> In comparing the older rocks of New York and of the East generally with those of the West, it should not be forgotten that there is a long interval on the line of the

[1] Physical geography and general geology. Geol. Surv. Wisconsin, Report, vol. 1, 1862, p. 14.
[2] Op. cit., pp. 20–23.
[3] Stratigraphical geology. Geol. Surv. Wisconsin, Rep., vol. 1, 1862, pp. 140–144.
[4] Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Regents Univ. N. Y., State Cab. Nat. Hist., 1863, pp. 119, 120.
[5] Op. cit., p. 120.
[6] Op. cit., p. 209.
[7] Op. cit., pp. 211–213.

northern outcrop of these ancient strata, between the St. Lawrence and the western limit of Michigan on the Menomonee River, where we can expect little aid from paleontology. The fossiliferous beds of these ancient formations in Wisconsin lie to the west of what appears to have been a great promontory at the time of their deposition, stretching southward from the region of Lake Superior far into the ancient sea. The disconnection caused by this promontory between the East and the West would of itself prepare us to expect a fauna differing in a great degree from beds of corresponding age on the opposite sides.

It has been shown, by the investigations of the Canadian Survey, that not only the Potsdam sandstone, but all the fossiliferous beds below the Birdseye and Black River limestones are absent from Kingston on Lake Ontario to Lacloche on Lake Huron. From Lacloche to Lake Superior there is a sandstone coming in below the Birdseye limestone, which, from its position, may be considered of the age of the Chazy[1] formation and equivalent to the St. Peters sandstone of Wisconsin and Minnesota; and it is this sandstone, doubtless, which has been taken for the Potsdam sandstone in some localities along that line.

The succeeding Birdseye and Black River formation, from Lacloche to Lake Superior, has become a buff-colored magnesian limestone, or weathering externally to this color, but still holding the characteristic fossils.

In New York a sandstone (the Potsdam) lies immediately beneath a magnesian limestone (the "Calciferous sandrock"): this deposit is succeeded by a calcareous formation (the Chazy), including a sandstone and surmounted by the Birdseye, Black River, and Trenton limestones.

In Wisconsin, Iowa, and Minnesota, we have undoubted Trenton limestone, and below it a buff-colored magnesian limestone containing so many of the characteristic fossils of the Birdseye and Black River limestones as to leave no doubt of the parallelism of these beds with those of New York. Below this magnesian limestone we have the St. Peters sandstone, corresponding, as already shown, with the Chazy formation; and beneath this a magnesian limestone, which, in its position and lithological character, corresponds in all respects with the "*Calciferous sandrock*" of New York.

It is from all these facts that the lower sandstone of the Upper Mississippi Valley has been placed in parallelism with the sandstone of New York known as the "Potsdam."

Notwithstanding, however, that this sequence is precisely like that observed in New York, it may not yet be regarded as proved that the sandstone, from which I have described these fossils, is in all respects the equivalent of the Potsdam sandstone of New York, Vermont, and Canada. It may represent more, or it may represent less than that formation. The *lower* accessible beds of the Mississippi Valley may represent the Potsdam of 150 or 200 feet in thickness in the typical localities in New York, while the middle and upper beds of the West may be of epochs not represented in that part of the series studied in New York; and in some other places, as in the regions just mentioned, the same epochs may be represented by a shaly or semicalcareous deposition, or may be included in the commencement of the Calciferous epoch. It should not therefore be regarded as decided that the Potsdam sandstone, as developed in New York, occupies the entire interval from the base of the oldest sedimentary formation of the Paleozic era to the Calciferous sandstone. From what we know of the primordial fauna in other localities, we are prepared to find beds above or below, or both above and below, the epoch represented (so far as now known) by the Potsdam sandstone of New York, and which may still be of the same period.

[1] The "Chazy formation" of the Canadian Geological Survey, in its eastern localities, includes a sandstone which comes in below the greater part of the limestone, leaving from 10 to 20 feet of shale and limestone beneath (Geology of Canada, 1863, p. 123). It is apparently this sandstone of the Chazy formation, having in Canada a thickness of 50 feet, which has become augmented in its western extension, while the calcareous part of the formation has partially or entirely disappeared.

He then enters upon the discussion of the relative age of the sandstones of Wisconsin and those of Lake Superior, and concludes that while the older beds of the latter area are apparently below the fossiliferous beds of the Upper Mississippi Valley, the newer sandstone of the St. Mary's River, which is apparently of the age of the St. Peter sandstone, or the Chazy formation, will be found overlying the fossiliferous sandstone, either with or without the intervention of the Lower Magnesian limestone.[1]

On a geological map of Wisconsin published in 1855 Mr. I. A. Lapham delineates the distribution of a sandstone occurring beneath the Lower Magnesian limestone. Under the same color he includes the sandstone on the south shore of Lake Superior, both on the north and southeastern side of the trap rocks of Keweenaw Point. The distribution of the fossiliferous sandstone south and southeast and east of the northern area of the primitive rocks is also laid down.[2] In a new geological map of Wisconsin, published in 1869, only the sandstones of the northwestern portion of the State are colored as Potsdam sandstone. In the vicinity of the shores of Lake Superior the Michigan area on the map of 1855 is left uncolored.

A paper on the age of the quartzites, schists, and conglomerates of Sauk County, Wisconsin, by Prof. R. D. Irving, proves conclusively that the quartzites are of pre-Potsdam age, and that the latter are deposited unconformably upon the flanks of the hill formed by the quartzites.[3] The evidence given by Prof. Irving negatives the conclusion arrived at by Dr. Alexander Winchell in his description of the fossils of Sauk County, where he states that Ptychaspis and Dikelocephalus occur at the base of the Potsdam, and that the quartzites in question are the lower beds of the Potsdam formation.[4] In the region of south-central Wisconsin, especially in Dane and Columbia Counties, Prof. Irving obtained a thickness of 800 feet for the lower or Potsdam sandstone, and for the superjacent Mendota limestone 30 feet, above which occurs the Madison sandstone, with a thickness of 35 feet. He refers only the lower or Potsdam sandstone to the Primordial.[5]

The sketch on the geology of northern Wisconsin by Mr. E. T. Sweet gives a general description of the Potsdam sandstone, and attention is called to the fact that all the strata at the falls of St. Croix belong to this sandstone formation and that none of them are of igneous origin, as suggested by Dr. Owen.[6]

---

[1] Op. cit., p. 220.

[2] Lapham, I. A.: Geological Map of Wisconsin. Milwaukee, 1855. Also a map for 1869.

[3] On the age of the quartzites, schists, and conglomerates of Sauk County, Wisconsin. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 95–99. Wisc. Acad. Sci. Trans., vol. 1, 1872, pp. 129–137.

[4] Notice of a small collection of fossils from the Potsdam sandstone of Wisconsin and the Lake Superior sandstone of Michigan. Am. Jour. Sci., 2d ser., vol. 37, 1864, pp. 226–232.

[5] Note on some new points in the elementary stratification of the Primordial and Canadian rocks of south central Wisconsin. Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 441, 443.

[6] Notes on the geology of northern Wisconsin. Wisc. Acad. Sci. Trans., vol. 3, 1876, p. 51.

A note on the age of the Crystalline rocks of Wisconsin by Prof. Irving states that the exact junction between the Potsdam and the Huronian formations is often to be seen, the almost loose sand of the Potsdam, with numerous fossils, together with fragments derived from the older rocks, lying upon and wedged in between the tilted edges of Huronian quartzite, schist, or other rock. Exactly similar unconformability is to be seen at the Dalles of the St. Croix River between the Potsdam and copper-bearing series; the horizontal beds of the former, filled with shells of Lingulella, lying directly upon the columar, melaphyre (?) of the latter series, the exact junction of the two series being exposed.[1]

The description of the geology of eastern Wisconsin by Prof. T. C. Chamberlin contains a detailed account of the "Potsdam sandstone." He says:

That it is the exact equivalent of the Potsdam sandstone of New York, as would seem to be implied by the name, is not absolutely certain, but as the term has been used to designate this formation in previous reports upon the geology of the State, and as the weight of evidence and authority favors this view, the name Potsdam sandstone will be used without further qualification in this report.[2]

The sandstone varies greatly in thickness, ranging from zero to about 1,000 feet. A detailed account of the formation is given with a list of the fossils found in the sandstone. The Madison sandstone and Mendota limestone are included as subdivisions of the terrane.

Reference to the description of the Lower or "Potsdam" sandstone series of central Wisconsin by Prof. R. D. Irving,[3] will be made under the description of the Potsdam terrane in Wisconsin.

A general description of the mode of occurrence and character of the Potsdam sandstone in the lead regions of northwestern Wisconsin was published by Mr. Moses Strong in 1877.[4]

Upon the basis of work in St. Croix, Dunn, and adjacent counties, Mr. L. C. Wooster subdivided the "Potsdam" as follows:[5]

The numbers indicate the distances below the Lower Magnesian limestone.

(*a*) Upper calcareous band: This varies greatly in thickness, and is the probable northwestern equivalent of the Mendota limestone near Madison; 75 to 85 feet.

(*b*) Lower calcareous band: The limestone characters and the thickness are more uniformly persistent than in *a*; 145 to 195 feet.

(*c*) Hudson trilobite beds: Quite rich in trilobites and brachiopods, including one new species of the former, with several undetermined ones; 150 to 200 feet.

(*d*) Glauconite layers: These comprise those layers which are very rich in glauconite. Crinoid stems were found in these at Hudson; 160 to 210 feet.

In *b*, *c*, and *d*, the lesser distance from the Lower Magnesian is true for western St. Croix County, while the greater is nearer true for points east.

---

[1] Note on the age of the Crystalline rocks of Wisconsin. Am. Jour. Sci., 3d ser., vol. 13, 1877, p. 308.

[2] (Geology of eastern Wisconsin.) Geol. Wisc., Surv. of 1873-'77, vol. 2, 1877, p. 257.

[3] (Geology of central Wisconsin.) Geol. Wisc., Surv. of 1873-'77, vol. 2, 1877, pp. 525-607.

[4] Geol. Wisc. Surv. of, 1873-'77, vol. 2, 1877, pp. 668-688.

[5] Work in St. Croix, Dunn, and adjacent counties. Geol. Surv. Wisconsin, Ann. Rep. for 1877, 1878 pp. 36, 37.

(*e*) Eau Claire trilobite beds: These hold at least seven species of trilobites, of which three are new, and a few brachiopods. These beds mark the lower limit of calcareous matter in the formation; 450 feet.

(*f*) Eau Claire grit: These layers mark the upper limit of the coarse sandstones, almost conglomerates; 680 feet.

The mode of occurrence and character of the "Potsdam" sandstone in the upper St. Croix district is described in great detail by Mr. Moses Strong.[1] In this he shows the unconformity between the "Potsdam" and the subjacent strata referred to the Keweenawan (Keweenaw) series, and describes the various sections of the sandstone exposed. The knowledge of the local details of the distribution and character of the "Potsdam" sandstone of the Mississippi region north of the Wisconsin River was increased by him in 1882 by the publication of many sections and descriptive details that will be used in a summary of our knowledge of the Cambrian rocks of that region.[2]

The "Potsdam" terrane of the lower St. Croix district was described by Mr. L. C. Wooster in the same volume with the report of Mr. Strong. This report also contains considerable data that will be referred to in the description of the Cambrian rocks of the region.[3]

The geographic distribution of the "Potsdam" sandstone and its relation to the subjacent pre-Cambrian rocks and the superjacent magnesian limestone is shown with great accuracy upon the general geological map of Wisconsin, published in 1881, and in the two sections at the bottom of the sheet.

A note by A. A. Young on the crystallized sands of the "Potsdam" sandstone of Wisconsin describes the manner in which the original grains of the sandstone are surrounded by crystalline envelopes of quartz.[4]

The summary of the geology of Wisconsin by Prof. T. C. Chamberlin contains a description of the rocks of the "Potsdam" period. These include the "Potsdam" epoch, the Lower Magnesian epoch, and the St. Peters epoch, in part. A general description of the formations, accompanied by an account of the life of each epoch, is followed by some general observations upon the Cambrian age, to which the formations are referred.[5]

The occurrence of a conglomerate formed of bowlders from the trap of the copper-bearing series in a matrix of sandstone that contains fragments of Linguloid shells, apparently *Lingulepis pinnaformis*, is noted by Mr. L. C. Wooster at a locality on the St. Croix River. From the mode of occurrence of the conglomerate he concludes that it must have

[1] Geology of the upper St. Croix district. Geology of Wisconsin, survey of 1873–1879, 1880, vol. 3, pp. 390–428.

[2] [Geology of the Mississippi region north of the Wisconsin River.] Geol. Wisconsin, survey of 1873–'79, vol. 4, 1882, pp. 38–91.

[3] [Geology of the lower St. Croix district.] Geol. Wisconsin, survey of 1873–'79, vol. 4, 1882, pp. 109–130.

[4] Further observations on the crystallized sands of the Potsdam sandstone of Wisconsin. Am. Jour. Sci., 3d ser., vol. 24, 1882, pp. 47–49.

[5] General Geology. Geol. Wisconsin, survey of 1873–'79, vol. 1, 1883, pp. 119–200.

accumulated along a cliff of the copper-bearing rocks and that the age of the conglomerate must be late "Potsdam."[1]

In an extended paper on the classification of early Cambrian and pre-Cambrian formations Prof. R. D. Irving illustrates the unconformity between the "Potsdam" sandstone and the subjacent Huronian and Keweenawan rocks. He also discusses the similar stratigraphic relations of the Cambrian and pre-Cambrian rocks of the Grand Cañon Region.[2]

MINNESOTA.

The presence of the lower sandstone along the Mississippi River below the Falls of St. Anthony to the Iowa line was proved by the survey of Dr. D. D. Owen in Wisconsin, Iowa, and Minnesota. Alternating exposures of the strata occur along the river and some of the tributaries flowing into it from the west.[3] On the accompanying map there is also a narrow area colored Potsdam along the valley of the Minnesota or St. Peter's River.

Little additional information in regard to Minnesota was published until Prof. N. H. Winchell, in the first annual report of the geological survey of Minnesota, discussed, under the title of "Potsdam Sandstone," the Sioux quartzite of northwestern Minnesota, and "The St. Croix Sandstone," the fossiliferous sandstone of the southeastern portion of the State, referred to the Potsdam by Dr. Owen.[4] Of the term "Potsdam," he says:

> This term is strictly applicable only to the sandstones of New York State, to which the name was first given, and to the equivalents of those strata in their extension through the West. It has been abundantly proved that the red sandstones of Lake Superior, however disturbed and changed locally, or however much increased in thickness by the agency of volcanic outbursts, are the exact equivalents of the New York *Potsdam*. They occupy the first position over the metamorphic slates of the *Huronian* rocks on which they lie unconformably, and from which they differ in being but slightly and only locally metamorphosed. They retain usually their evidently sedimentary characters, and have not well preserved fossil remains.[5]

He states further that in Wisconsin the upper sandstones are found to lie unconformably upon the red sandstones where they have been tilted by volcanic agency, thus referring the quartzite of Sauk County to the Potsdam, and the superjacent fossiliferous, Upper Cambrian sandstones that have been correlated by authors with the Potsdam of New York, to his St. Croix sandstone. The red sandstone or Sioux quartzite is said to be both older than and unconformable with the

[1] Transition from the copper-bearing series to the Potsdam. Am. Jour. Sci., 3d ser., vol. 27, 1884, pp. 463–465.

[2] On the classification of the early Cambrian and pre-Cambrian formations. U. S. Geol. Surv., 7th Ann Rep. for 1885–'86, 1888, pp. 365–454.

[3] Geol. Surv. of Wis., Iowa, and Minn., and incidentally of a portion of Nebraska Territory, Philadelphia, 1852, pp. 48, 49.

[4] General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey Minnesota, 1st Ann. Rep. for 1872–'73, 1st ed., pp. 68–80.

[5] Op. cit., p. 68.

light-colored sandstones that occupy a conspicuous place in the bluffs of the Upper Mississippi, below the Lower Magnesian limestone. Of the *Sioux quartzite* he says that—

Its features here are easily identifiable with those of the Potsdam at the rapids in the St. Mary's River, at Sault Ste. Marie, Michigan. In their passage to the west, the over-lying, light-colored sandstones seem to become more largely developed. They acquire a thickness, including the intercalated beds of shale, of about 600 feet in their exposures along the Mississippi River.[1]

Of the fossils collected from the horizontal beds at the Falls of the St. Croix it is said they:

Were described as coming from the *Potsdam sandstone*, and were supposed to belong to a horizon much lower than that of the *Lingula Beds* of the *Potsdam* of New York. The name has been still further removed from its original use by the Iowa geologists, *in its application only to these upper beds*, and in giving the name *Sioux quartzite* to the western representative of the original *Potsdam*. Dr. Owen, although he recognized many points of difference between the Lake Superior and New York *Potsdam*, and these light-colored sandstones of the St. Croix and Upper Mississippi, seems not to have noted the important fact that the former are everywhere subject to distortions and fractures by volcanic forces, while the latter are never known to be disturbed by such causes. It is true that he embraces both the red and the light-colored sandstones in the designation of "Potsdam," and argues at length to prove the great age of the red. (Geological Survey of Wisconsin, Iowa and Minnesota, p. 187.)

It is in accord with geological precedent, therefore, to separate these two sandstone formations under different names, retaining the name of *Potsdam* for the older, and giving provisionally the name of the St. Croix River, on which they are best exposed, to the latter.

The following reasons may be assigned:

(1) The *Potsdam* beds were laid down before the close of the volcanic disturbance so evident in the rocks of the early Silurian and pre-Silurian ages; the *St. Croix* beds were deposited and still lie in horizontal layers, unconformably not only over the *Laurentian* and latest trappean rocks of the northwest, but also on the upturned beds of the Potsdam.[2]

(2) This reason has little bearing and will not be quoted.

(3) The lithological characters of the *Potsdam* beds are uniformly different from those of the *St. Croix* beds. The former are hard and often vitreous, usually of a brick-red color. Their bedding is very distinct, and often separated into slaty layers by partings of red shale. They are strongly marked by the so-called fucoidal impressions. They are frequently ripple-marked and sun-cracked. The latter are white or buff-colored, often friable, and constitute a heavy bedded or massive sandstone, of handsomely rounded quartzose grains.

(4) This notes differences in chemical composition.

(6) The *Potsdam sandstone* has a thickness of at least 400 feet; (Note—D. Owen makes the thickness of the Potsdam (red sandstones of Lake Superior) over 5,000 feet. See Owen's report on Wisconsin, Iowa, and Minnesota, p. 193); the *St. Croix* sandstone also has a thickness of over 500 feet. It is more in keeping with the canons of geological nomenclature to give separate titles to formations so well defined and so largely developed.

(7) This gives the evidence of paleontologic differences. He states that the fossils of the Potsdam sandstone of New York are *Lingula*

[1] *Op. cit.*, p. 69. [2] Op. cit., pp. 69, 70. [3] 5th does not occur in the original.

antiqua (Con.) and *Lingula prima* (Con.), a Discina (or Orbicula), and uncertain impressions supposed to be of a Pleurotomaria and of crinoidal remains. A species of Theca has also been described from Keeseville. In comparison to this he cites a large number of species described by Owen and Hall from Wisconsin.[1]

(8) In this it is shown that the number of species of the Lake Superior district and from the New York district, in the sandstone referred by him to the Potsdam sandstone, are the same, namely three.

Notwithstanding these considerations, it has not been thought best to attempt the delineation of the areas of these sandstones separately on the preliminary geological map accompanying this report.[2]

A detailed description of the lithological characters of the St. Croix and Potsdam sandstone is also given.[3]

The preceding observations by Prof. Winchell have been quoted in detail as they are the foundation for the theoretical views subsequently advanced by him correlating the Potsdam sandstone of New York with various other sandstones of pre-Silurian age.

On the map accompanying the report (opposite p. 45) the Sioux quartzite area of northwestern Minnesota is colored the same as the St. Croix sandstone of the southeastern portion of the State. In the legend the color is placed under the heading of Potsdam and St. Croix.

In the fourth annual report Prof. Winchell describes the St. Croix sandstone as it occurs in Fillmore County and illustrates the geographic distribution on an accompanying map.[4] In some notes on a deep well drilled at Minneapolis, Minnesota, the same writer states that Nos. 11, 12, and 13 represent the St. Croix sandstone with a total thickness of 217 feet. Beneath this there is a red marl and red sandstone which he refers to the same horizon as the catlinite beds of the Sioux quartzite series. Of No. 14 it is said: "No. 14 may represent the Lingula flags or the upper portion of the Potsdam, so called." No. 15 is correlated as undoubtedly the upper portion of the great series of marls and sands which characterize this horizon in Minnesota. "It is the same formation as the rock that embraces the well known 'pipestone' or catlinite of Minnesota."[5]

The Sioux quartzite is referred by Prof. Winchell to the Potsdam sandstone in a description of the geology of rocks in Pipestone County in the sixth annual report.[6] It includes the famous pipestone quarry near the center of Pipestone County.[6]

A more extended account of the strata referred to the "Potsdam" sandstone is published by Prof. Winchell in the tenth annual report

[1] Op. cit., p. 71. [2] Op. cit., p. 73. [3] Op. cit., pp. 75-80.

[4] Report on the geology of Fillmore County. Geol. and Nat. Hist. Surv., Minnesota; 4th Ann. Rep. for 1875, 1876, pp. 31-32.

[5] Notes on the deep well drilled at East Minneapolis, Minnesota, in 1874-'75. Minn. Acad. Sci., Bull., vol. 1, 1876, pp. 188-189.

[6] The geology of Rock and Pipestone Counties. Geol. and Nat. Hist. Survey, Minnesota, 6th Ann. Rep., for 1877, 1878, p. 97.

of the survey. In this he affirms that the horizontal fossiliferous beds referred to the Potsdam by Dr. Owen, Prof. Hall, and other authors is above the true Potsdam of New York, and that the latter is represented by the rocks of the copper-bearing series in the west; also, that no fossils representing the Primordial fauna have yet been discovered in the west nor have any been found in the western representative of the Potsdam; and finally, that the second fauna of Barrande is found in the Quebec group of Canada and in the St. Croix sandstone of the west, lying in each case above the Potsdam sandstone.[1]

An article by Dr. J. H. Kloos, translated by Prof. Winchell, describes the rocks of the Falls of St. Anthony and the St. Croix River, and gives a description and a diagrammatic section of the river bank at Taylor's Falls, illustrating an unconformity between the Potsdam sandstone and the subjacent copper-bearing rocks.[2]

In an account of the geology of a deep well drilled at Minneapolis Prof. Winchell states that the drill passed through sandstone in the lower portion of the well as indicated in the following section:[3]

	Feet.
1. Drift	10
2. Trenton limestone	24
3. Light, crumbling sandstone (St. Peter?)	125
4. Brown-red pipestone clay	2
5. Potsdam sand	42
6. Red quartzite, Potsdam	102
7. Light-colored Potsdam sand and shales	722
8. Red Potsdam sandstone and shales at least	347
	1,374

Particular attention is called to the brown-red pipestone clay of the section, which is the equivalent of No. 12 of that section on page 212. No. 6 of the section quoted is compared to a layer of red quartzite, seen at New Ulm, Minnesota, and at Baraboo, Wisconsin. Commenting upon this he says:

> Thus we find an interbedded red quartzite in the Potsdam formation similar to those seen in the same formation in the Black Hills and in several other places in the Rocky Mountain region.[4]

Attention is called to this statement as it is a correlation of a quartzite of the Upper Cambrian rocks of the Black Hills with a bed of quartzite in the Sioux quartzite series of Minnesota and the Baraboo quartzite series of Wisconsin.

In a tabulation of the strata beneath the lower fossiliferous sand-

[1] The Potsdam Sandstone. Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, p. 136.

[2] Geological notes on Minnesota. (Translated by N. H. Winchell.) Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, pp. 186–200.

[3] The geology of the deep well drilled by C. C. Whelpley at Minneapolis, at the "C" Washburn Mill. Geol. and Nat. Hist. Survey Minnesota, 10th Ann. Rep. for 1881, 1882, p. 217.

[4] Op. cit., p. 214.

stone or St. Croix sandstone, Prof. N. H. Winchell defines the Potsdam formation as follows:[1]

Potsdam formation.—Tilted red sandstones, shales and conglomerates, changed by igneous gabbros and dolerites locally to red quartzites, felsites, quartz-porphyries and to red granite. The Keweenian and Huronian in part, in Wisconsin.

He places the Taconic group second and defines it as follows:

Taconic group.—Horizontal black slates and gray quartzites, with interbedded limestones and diorites (the Animikie group), changed to tilted slates, quartzites, iron ores, and silicious marble. The Gunflint beds, the Mesabi iron rocks, the Ogishke Muncie conglomerate (?), the Thomson slates and quartzites, the Vermilion iron rocks; the Huronian in part, in Wisconsin and Michigan.

A description of the Sioux quartzite as it occurs at New Ulm is given by Prof. Winchell in the second annual report.[2] In the first volume of the final report of the Minnesota survey he describes the St. Croix sandstone as it occurs in Houston, Winona, and Fillmore Counties.[3] The entire thickness of the formation in Winona varies from 488 to 558 feet.[4] Under the title of Potsdam quartzite a description is given in this volume by Messrs. Winchell and Upham of the pre-Cambrian quartzite of northwestern Minnesota.[5]

From the Sioux quartzite series at Pipestone, Minnesota, Prof. Winchell described, in 1885, *Lingula calumet* and *Paradoxides barberi*, referring them to the equivalent of the Potsdam sandstone of New York.[6]

In a note on the revision of the stratigraphy of the Cambrian in Minnesota, Prof. Winchell includes under the St. Croix terrane, Jordan sandstone, St. Lawrence limestone, shales, and Dresbach sandrock.[7] It is interesting to note that after the upper member of the St. Croix, the Jordan sandstone, we find "Potsdam" (?); also after the Dresbach sandstone at the base and (Potsdam) after formations placed as pre-St. Croix.

The geological age of the Sioux quartzite of the pipestone quarries in Dakota and Minnesota is discussed by Prof. R. D. Irving,[8] who concludes that their tilted position, great thickness, and lithological contrast with the Potsdam sandstone "make it evident that they are not merely a downward continuation of that formation, but, on the contrary, form a great unconformably underlying series."

[1] Notes on the age of the rocks of the Mesabi and Vermilion iron districts. Geol. and Nat. Hist., Survey Minnesota, 11th Ann. Rep. for 1883, 1884, p. 170.

[2] The geology of the Minnesota Valley. Geol. and Nat. Hist. Surv., Minn. 2d Ann. Rep. for 1873, 1874, p. 157.

[3] The Geology of Minnesota. Vol. 1, of the Final Report, 1884, pp. 223–227, 257–259.

[4] Op. cit., p. 258.

[5] Op. cit. pp. 422–424, 499–503.

[6] Fossils from the red quartzite at Pipestone. Geol. and Nat. Hist. Surv. Minnesota, 13th Ann. Rep. for 1884, 1885, pp. 65–72.

[7] Revision of the stratigraphy of the Cambrian in Minnesota. Geol. and Nat. Hist. Survey Minnesota, 14th Ann. Rep. for 1885, 1886, p. 337

[8] Preliminary paper on an Investigation of the Archean formations of the Northwestern States. U. S. Geol. Surv. 5th Ann. Rep., 1883–84, 1885, pp. 201, 202.

Mr. Warren Upham in notes on the geology of Minnehaha County, Dakota,[1] refers to the rocks in various portions of Minnehaha County as "*Typical Potsdam quartzite*," but he mentions no reasons for concluding it to be of this age. No fossils were found in it.

In the second volume of the Geology of Minnesota Prof. N. H. Winchell states that the St. Croix formation in Wabasha County is about 250 or 300 feet in thickness; and it is not known to vary particularly in its stratigraphic composition from that of Winona County.[2] In the account of the geology of Goodhue County he describes the formation and accompanies it with a list of the fossils found in the St. Croix formation in the Upper Mississippi Valley.[3]

In the same volume Mr. Warren Upham describes the St. Croix sandstone as it occurs in Chisago County, in the valley of the St. Croix River.[4] He also describes the formation as it occurs in Pine County, along the upper portion of the St. Croix River.[5]

In an article on the age of the St. Croix sandstone, Prof. N. H. Winchell discusses its relations to the typical Potsdam of New York and concludes it is a distinct formation.[6] In an account of a deep well drilled at Stillwater, Minnesota, it is stated by Mr. A. D. Meads that—

> The well starts at about 740 feet above the sea, and after passing through 701 feet of drift, white friable sandstone, and green shales belonging to the St. Croix and so-called Potsdam of the Northwest, enters a series of dark red and brown shales and brown feldspathic sandstones which exhibited a thickness of more than 1,500 feet. These gradually assume characters of a volcanic detrital tuff—"amygdaloidal," calcitic, kaolinic, still brown, slightly siliceous—and finally at the depth of about 3,300 feet unmistakable beds of trap rock were encountered, alternating with sandstone beds. At this depth some grains of native copper were seen in the drillings.[7]

Prof. N. H. Winchell has recently published his latest conclusions on the Taconic rocks of Minnesota. On the evidence of the tracks described by Mr. G. F. Matthew[8] he considers the Taconic (Lower Cambrian) age of the "Animike" formation to be sufficiently established, and thinks the name Taconic should be substituted for Animike.[9] The Pewabic quartzite is referred to the base of the "Animike," although he says: "it was at first supposed to be the equivalent of the Potsdam (Paradoxides horizon) which apparently overlies the "Animike."[10]

A correction is made in relation to the reference of the stratigraphic position of the Granular quartz as follows:[11]

---

[1] Notes on the geology of Minnehaha County, Dakota. Geol. and Nat. Hist. Survey, Minnesota, 13th Ann. Rep. for 1884, 1885, pp. 88–97.

[2] The Geology of Minnesota. Vol. 2 of Final Report, 1888, p. 13

[3] Op. cit., pp. 31–36.

[4] The Geology of Minnesota. Vol. 2, Final Report, 1888, pp. 407, 409.

[5] Op. cit., pp. 637–642.

[6] Geol. and Nat. Hist. Surv. of Minn., 17th Ann. Rep. for 1888, 1889, pp. 56–64.

[7] The Stillwater Deep Well. American Geologist, vol. 3, 1889, p. 342.

[8] Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 145.

[9] The iron ores of Minnesota. Geol. and Nat. Hist. Surv. Minnesota. Bull. No. 6, 1891, p. 113.

[10] Op. cit., p. 125.

[11] Op. cit. Foot note on pp. 417, 418.

The writer wishes to correct the view published by him in the American Geologist a few years ago ("A Great Primordial Quartzyte," vol. 1, p. 178), that the granular quartz probably overlies the black slate of the Taconic system, and is equivalent of the Red sandrock of Vermont. The Red sandrock appears to be a part and near the top of the "Georgia series" and above the Winooski marble, but the "granular quartz" lies below the Winooski marble. The typical Potsdam is probably the "granular quartz." But the Red sandrock, and also some light-colored, loose sandstones still higher have very largely been regarded its equivalent.

IOWA.

On the map accompanying Dr. D. D. Owen's report of the geological survey of Wisconsin, Iowa, and Minnesota a small area is colored as the Potsdam sandstone of New York, in the northeastern corner of the State.[1]

As State geologist of Iowa, Prof. J. Hall stated that the Potsdam sandstone attains its greatest exposures in Minnesota and Wisconsin north of the limits of Iowa, and about the regions of Lake Pepin. The excavation of the Upper Iowa River, however, has removed the calciferous sandstone; so that at the junction of that river with the Mississippi there is exposed a broad belt of the lower rock. A general description of the sandstone is given with the statement that some slightly calcareous bands contain fragments of trilobites. In numerous localities shells of Lingula are found, though by no means so abundantly as in the same rocks in Minnesota. These fossiliferous bands appear in the vicinity of Lansing.[2] In the same volume there is a general account of the Potsdam or inferior sandstone by Prof. J. D. Whitney.[3]

In a general description of the geology of Iowa Dr. C. A. White describes the Sioux quartzite as occurring in the extreme northwestern corner of the State. In the table of classification he places it as Huronian (?) and beneath the Potsdam sandstone.[4] This is the quartzite referred to the Potsdam in Minnesota by Prof. N. H. Winchell. In describing the Potsdam sandstone Dr. White states that it reaches a known thickness in Iowa of 300 feet, and it is exposed only in a small portion of the northeastern corner of the State.[5]

In the account of a deep well at Emmetsburg, Iowa, Prof. N. H. Winchell refers to a white sandstone found beneath the blue shales of St. Croix, assigning it a thickness of 107 feet. The rock beneath this, which Mr. Swan, who kept a record of the well, called granite, is referred to the Potsdam quartzite.[6]

[1] Geol. Surv. of Wisc., Iowa, and Minn.; and, incidentally, of a portion of Nebraska Territory, Philadelphia, 1852.

[2] Geology of Iowa, vol. 1, 1858, pp. 47–48.

[3] Ibid., pp. 328–331.

[4] General geology. Azoic, Lower Silurian, Upper Silurian, and Devonian systems. Geol. Surv. Iowa, Rep., vol. 1, 1870, p. 168.

[5] Op. cit., p. 172.

[6] Section of a deep well at Emmetsburg, Iowa. Minn. Acad. Sci. Bull., vol. 1, 1880, pp. 387, 388.

In describing a deep well at Washington, in southeastern Iowa, Prof. S. Calvin states that a gray sandstone 1,230 feet from the surface probably represents the upper part of the Potsdam series.[1]

LAKE SUPERIOR SANDSTONE.

In an account of a journey along the south shore of Lake Superior, Dr. J. J. Bigsby describes a red and white sandstone, for the most part horizontal, that predominates along the shore, resting in places on granite.[2] He also mentions the red sandstone of Point Keewawoonan and the sandrock described to him by Mr. Thomson.[3]

The description of the geology of Lake Superior, by Capt. H. W. Bayfield, mentions a horizontally stratified sandstone that he traced from one extremity of the lake to the other, on both the north and south shores, and on many of the islands in the lake. A description of the mode of occurrence of the sandstone on the south shore of the lake is given, with several diagrams illustrating the unconformity between the granite and the sandstone.[4] He considers it quite probable that the formation extended to the west and southwest as far as the foot of the Rocky Mountains, and that it might possibly be the same as the sandstone at the Falls of Niagara, etc., but concluded it required much more elaborate investigation than has yet been bestowed to render it certain that the sandstone of Lake Superior and that of the extensive tracts of country mentioned are the same formation. He then gives reasons for terming the sandstone of Lake Superior the Old Red. These are its position immediately on the granite, its structure, and component parts.[5] No fossils were observed. The student will find in this paper of Capt. Bayfield's a very fair description of the sandstones as they occur about Lake Superior, and it is worth reading in connection with the controversy in relation to their age.

As State geologist of Michigan Dr. Douglass Houghton reported upon the strata of the northern peninsula. In the second annual report he says that "the *Old Red sandstone*" has been very much shattered by the protrusion of trap rock through it.[6] In his third report a more extended account is given of the Lake Superior sandstone on the Ste. Marie River. The sandstone passes conformably beneath the superjacent limestone.[7] Of the bulk of the formation he says:

> The Lake Superior sandstone in its easterly prolongation does not attain a very great thickness, but in proceeding westerly this thickness is vastly increased, attaining on the south shore of Lake Superior to several hundred feet.

---

[1] Notes on the formations passed through in boring the deep well at Washington, Iowa. American Geologist, vol. 1, 1888, p. 30.

[2] Notes on the geography and geology of Lake Superior. Quart. Jour. Lit., Sci. and Arts (of the Royal Inst. of Gt. Brit.) vol. 18, 1825, p. 33.

[3] Op. cit., p. 260.

[4] Outlines of the geology of Lake Superior. Quebec Lit. and Hist. Soc. Trans., vol. 1, 1829, p. 17, figs. 2 and 3, on plate.

[5] Op. cit., p. 19.

[6] (Peninsula District.) Second annual report State geologist of Michigan, Detroit, 1839, p. 14.

[7] Third annual report State geologist of Michigan. House Reps. Document, No. 8, 1840, p. 14.

So far as my examinations during the past year have extended the rock is destitute of fossils, and in fact after a careful examination (several years ago) along its whole line of outcrop, on the southerly shore of Lake Superior, I have never been able to detect in the rocks a single contained fossil.[1]

The fourth report describes the "lower or red sandstone and shales" as follows:

The red sandstone, with its accompanying red and gray shales, occupies a much larger extent of the country bordering upon Lake Superior than any other single rock or group of rocks. It rests upon the primary and metamorphic rocks immediately west from Chocolate River; upon the conglomerate and mixed rocks from near Eagle River, of Keweenaw Point, west to the head of Lake Superior; upon the primary trap, metamorphic and conglomerate rocks of the north shore of the lake, and upon the conglomerate rock of Isle Royale. It is this rock which forms the basis of the level plateaus or valleys occupying the spaces between the several ranges of hills south from Lake Superior, and west from Chocolate River. In these last situations this rock is frequently seen undisturbed to surround the bases of isolated knobs of granite, though when near to or in contact with knobs or [of] trap there are invariable evidences of very great disturbance.[2]

A second bed of sandstone is described as the "upper or gray sandstone." "Upon the shore of Lake Superior, and extending from Point Iroquois to Grand Island, a sandstone occurs, differing widely in its appearance from that before described. This sandstone rests *unconformably* upon the red sandstone, the former dipping gently to the south or southeast, while the latter dips very considerably to the north or northwest."[3]

A sandy limerock rests conformably and immediately upon the upper or gray sandstone. The tabulation of the rocks of the Upper Peninsula is as follows:[4]

9. Tertiary clays and sands.
8. Upper limerock group (embracing as members the Drummond Island and Mackinaw limestones).
7. Lower lime rock and shales.
6. Sandy or intermediate limestone.

		Thickness.
5. Upper or gray sandstone, mean	feet	700
4. Lower or red sand rock and shales, extreme	do	6,500
3. Mixed conglomerate and sand rock, extreme	do	4,200
2. Conglomerate rock, extreme	do	5,260

1. Metamorphic, trap, and primary rocks.

A detailed account of the red sandrock and shales is given on pages 37 to 41. This is followed by a description of the upper or gray sand rock, of which he says:

The only remaining rock which separates the red sandrock from the limestone lying to the south is a gray or brownish sandrock that is almost wholly composed of grains of quartz, usually feebly cemented with calcareous matter. The composition of this rock differs from that of the lower sand rock in being more exclusively quartz, while in epoch of deposition the rock under consideration should not be confounded with that of the red sandstone. It has already been stated that the red sandrock of

[1] Op. cit., p. 15.
[2] Fourth Ann. Rep. State geologist of Michigan, 1841, pp. 18, 19.
[3] Op. cit., p. 19.
[4] Op. cit., p. 22.

the south coast dips regularly northerly, while the upper or gray sandstone dips equally regularly south or southeasterly, in which respect the last-mentioned rock conforms to the limestones resting upon it, while it rests itself upon the uptilted edge of the red sandrock below.[1]

The upper sandrock, like the lower, abounds in clearly defined ripple marks, and its line of cleavage is very irregular, frequently being opposed to the line of stratification over very considerable districts of country. Two indistinct species of fucoides were all the fossils noticed in connection with it.

I was unable to obtain any observations upon the thickness of the upper sand rock which were satisfactory, but from the imperfect observations which were obtained I was led to conclude that the average thickness as far westerly as the Pictured Rocks does not vary far from 700 feet. The upper sandrock, like the rocks before mentioned, wedges out as far as we proceed in an easterly direction.[2]

When presenting to the Boston Society of Natural History an account of his visit to Lake Superior Prof. H. D. Rogers states that he discovered in the neighborhood of Chocolate and Carp Rivers the following conditions of stratification:

First, a group of rocks, the equivalents, undoubtedly, of the Primal sandstone and Primal slate of Profs. W. B. Rogers and H. D. Rogers, denominated, in the nomenclature of the New York survey, the Potsdam sandstone, and these rocks, highly inclined, and traversed by parallel east and west axes. Secondly, upon the uptilted edges of this earliest Paleozoic formation rests, in an unconformable position and with a very gentle northern dip, the conglomerates and shales of the red sandstone series. Specimens of the conglomerate were displayed, in which the pebbles were all from the older rocks. Mr. Rogers thought this fact of unconformable superposition an almost conclusive proof of a post-Paleozoic date; and he proceeded to argue, from various points of analogy between the red sandstone itself, its trappean dikes, and their mineral associations, with similar components of the Mesozoic or new red sandstone of the Atlantic States, that the formation in question is of equivalent age and origin with this last-named interesting group of rocks.[3]

In his reconnaissance of the Chippewa land district of Wisconsin, Dr. D. D. Owen examined a portion of the shores of Lake Superior. He noted the red sandstone, its mode of occurrence, and character. He states that various views have been advanced by different writers regarding the age of the red sandstone, marls, and conglomerates of Lake Superior. Some authors have referred them to the date of the oldest sandstones of the New York system; others believe them to be contemporaneous with the New Red sandstone of Great Britain and the *bunter Sandstein* of Germany. He further states:

Judging, however, from lithological and mineralogical character, there certainly is strong presumptive evidence that they were deposited subsequently to the Carboniferous era.

He calls attention to the strong resemblance between them and the formations above the Coal Measures, not only of the State, but of some parts of Europe.

Ranging through Connecticut, New Jersey, Maryland, and Virginia there are red sandstone and marly beds that are almost a counterpart of some portion of the Lake Superior formations, as well in aspect as in composition; like them, too, they are

[1] Op. cit., pp. 41, 42.

[2] Op. cit., pp. 42, 43.

[3] *On* the mineralogy and geology of the south shore of Lake Superior. Boston Soc. Nat. Hist. Proc. vol. 2, 1846, p. 125.

traversed by ranges of intrusive trap, with accompanying veins of copper. * * * To draw up in detail a comparison between these formations and those of the Northwest would, at this early stage of the survey of Wisconsin, be premature.[1]

In 1849 Prof. C. T. Jackson argued that the red sandstone and conglomerate rocks of Keweenaw Point existed there anterior to the elevation of the trap rocks, and that the eastern sandstone and the red sandstone were the same in geologic age. After reviewing the mode of occurrence and the relation of the sandstone to other rocks, especially a limestone from which a fragment of *Pentamerus oblongus* was obtained, indicating the upper member of the Niagara, New York series, he concluded that the sandstone of Keweenaw Point was not of the Potsdam series, but that it was most probably the New Red, or that system of sandstones which is regarded as such in New England.[2]

In their report of 1849 Messrs. Foster and Whitney color the accompanying map of Keweenaw Point so as to indicate that they consider the sandstone and conglomerate superior to the trap series, forming the base of the Silurian system. The same coloring and nomenclature are used on the map of the district between Mackinaw Bay and Chocolate River, and that between Portage Lake and Montreal River and Isle Royale.[3]

In the same volume, following the report by Foster and Whitney, is a general description of the region between Keweenaw Point and Montreal River. The writer says the age of the sandstone of Lake Superior could not be determined by any evidence he had been able to collect. It is entirely destitute of fossils, and lies directly upon granitic rocks.[4] Whether it is written by Mr. Foster or Prof. Whitney is not stated.

Mr. J. W. Foster states that he is disposed to regard the sandstone of Lake Superior as resting at the base of all the fossiliferous rocks.[5] He evidently considered the horizontally bedded sandstone at Keweenaw Point the same as the disturbed sandstone on the opposite side. Full descriptive details of the sandstones at Keweenaw Point are also given by Mr. W. A. Burt.[6] In the same report Mr. Bela Hubbard states that the Red sandrock is the equivalent of the Potsdam red sandrock of the New York reports, and that on the map the geographic distribution skirts the trap range on both sides, but having by far its broadest extension on the south side.

---

[1] Report of a geological reconnaissance of the Chippewa land district of Wisconsin; and incidentally of a part of Iowa and of the Minnesota Territory, 30th Congress, 1st sess., Senate Ex. Doc. No. 57, 1848, pp 57–58.

[2] Report on the geological and mineralogical survey of the mineral lands of the United States in the State of Michigan, Ex. Doc. No. 5, House of Reps., 31st Congress, 1st sess, part 3, 1849, pp. 398, 399, 452.

[3] Synopsis of the explorations of the geological corps in the Lake Superior land district in the northern peninsula of Michigan, Ex. Doc. No. 5, House of Reps., 31st Congress, 1st sess., part 3, 1849, pp. 605 625.

[4] Op. cit., p. 655.

[5] Notes on the geology and topography of portions of the country adjacent to Lakes Superior and Michigan, in the Chippewa land district, Ex. Doc. No. 5, 31st Congress, 1st sess., part 3, 1849, p. 781.

[6] Topography and geology of the survey of a district of township lines south of Lake Superior, 1845, H. R. Ex. Doc. No. 5, part 3, 1849, pp. 815–839.

It here lies in nearly horizontal strata, though at the coast a slight dip inland is observable, becoming more apparent as it approaches the basin of Portage Lake. In its approach to the trap, however, it is found more or less tilted from its original horizontal position, and is also very much altered by its contact with that igneous rock. The evidences both of the deposition of this extensive rock formation in calm and shallow waters and of the subsequent change induced in it by the trap rocks when in a fused or heated state are very important.[1]

In their report upon the copper region of Lake Superior, Messrs. Foster and Whitney tabulate the stratified sedimentary rocks as follows:[2]

I. *Conglomerate.*—Not strictly a sedimentary rock, but a volcanic tuff.

II. *Inferior sandstone.*—Potsdam sandstone.

III. *Compact or Lower Magnesian limestone.*—Calciferous sandstone, Chazy limestone, Bird's-eye and Black River limestone.

This table is followed by a detailed description of the conglomerate, sandstone and superjacent limestone. No attempt is made to differentiate the horizontally bedded Red sandstone, of Keweenaw Point, from the banded sandstone that occurs on the western part of the Point.

Of the transition of the sandstone to the magnesian limestone they say:

The sandstone, as we ascend from the lower strata to the higher, is found to be less colored by the oxides of iron, and to take into its composition particles of lime until finally it passes into well characterized, compact, magnesian limestone. * * * We apply the term magnesian to this belt to define its lithological characters, although the associated organic remains would seem to indicate the presence of several of the lower Silurian groups, which can not be recognized by lithological differences.[3]

A notice of the work by Foster and Whitney in the copper district was published in the American Journal of Science, 2d series, volume 12, 1851, pp. 222–239.

In a letter describing the Silurian terrane of Lake Superior, Messrs. Foster and Whitney reaffirm their opinion that the standstones of Lake Superior are of the age of the Potsdam of the New York series, and that the section exhibits the Azoic system at the base, upon which rests the conglomerate, formed of igneous rocks, and then in turn the Potsdam sandstone, the Calciferous sandstone, the Trenton limestone, etc.[4]

In commenting upon this statement of Messrs. Foster and Whitney, that the Lake Superior sandstones are of the same age as the Potsdam sandrock of New York, Prof. Jules Marcou disputes their correlation and considers the formation as equivalent to the New Red sandstone, as was stated by Prof. Jackson.[5]

---

[1] General observations upon the geology and topography of the district south of Lake Superior, subdivided in 1845 under Houghton, House of Reps., Ex. Doc. No. 5, part 3, 1849, p. 840.

[2] Report on the geology and topography of a portion of the Lake Superior land district in the State of Michigan. Washington, 1850. Stratified and sedimentary rocks. Vol. 1, 1850, p. 99.

[3] Op. cit., p. 117.

[4] (Aperçu de l'ensemble des Terrains Siluriens du lac Supérieur.) Bull. Soc. géol. France, 2e sér., vol. 8, 1850, p. 91.

[5] Response a lettre de MM. Foster et Whitney sur le lac Supérieur. Bull. Soc. géol. France, 2e sér., vol. 8, 1850, pp. 101–105.

In their report on the geology of the Lake Superior land district, Messrs. Foster and Whitney describe, under the heading of "Potsdam sandstone,"[1] a sandstone on the north shore, occurring in insulated patches on the isthmus between Thunder and Black Bays. This sandstone attains, according to Logan, a thickness of at least 200 feet.[2] On the south shore the sandstones of the northwestern side of Keweenaw Point are considered to be of the same age as those on the south side of the point, extending along the lake shore from Keweenaw Bay to St. Mary's River. The sandstone extending southward, subparallel to the bay, is also correlated with the sandstone mentioned; and all of these are correlated with the Potsdam sandstone of the New York series. They quote from the manuscript of Prof. James Hall in relation to the westward extension of the sandstone in Wisconsin, in the Upper Mississippi Valley.[3]

In some observations on the age of the sandstones of the United States Prof. C. T. Jackson concludes that the Lake Superior sandstone is of Upper Silurian age.[4]

Messrs. Foster and Whitney returned to the discussion of the age of the sandstone of Lake Superior in 1851 and conclude there can no longer be any doubt that this sandstone lies below the lowest fossiliferous members of the Silurian in the position of the Potsdam sandstone of New York.[5] They describe with considerable detail the mode of occurrence of the horizontally bedded sandstone at the southeastern end of the lake along the Sault Ste. Marie, with its extension westward along the coast to Keweenaw Bay. They show it to be one continuous formation around the great central granitic and azoic nucleus; that it is a granular, quartzose material, mostly friable, and containing little iron; that the thickness of the whole formation did not exceed 100 feet at Sault Ste. Marie, and that at the Pictured Rocks it was probably more than 300 or 350 feet, gradually increasing from the east toward the west.[6] They then describe a sandstone on the western side of the Keweenaw Point and Isle Royale which is now referred to the Algonkian. This is the best résumé of the information relating to the Lake Superior sandstone published up to its date.

In his tabulation of the lowest Protozoic sandstones Dr. D. D. Owen places the Lake Superior ferruginous and argillaceous sandstones, shales, and conglomerates at the base of the section, assigning it a thickness of 5,000 feet.[7] On the accompanying map the Lake Superior

[1] Lower Silurian System. Potsdam and Calciferous Sandstones. Rept. on Geol. of Lake Superior Land Distr., Pt. 2, 1851, pp. 113-134.

[2] Op. cit., p. 115.

[3] Op. cit., pp. 133, 134.

[4] [Some observations on the age of the sandstones of the United States.] Bost. Soc. Nat. Hist. Proc., vol. 3, 1851, pp. 335, 336.

[5] On the age of the sandstone of Lake Superior, with a description of the phenomena of igneous rocks. Am. Assoc. Proc., vol. 5, 1851, p. 25.

[6] Op. cit., p. 29.

[7] Geol. Surv. of Wis., Iowa, and Minn., and, incidentally, of a portion of Nebraska Territory. Philadelphia, 1852, p. 53.

sandstone west of the Montreal River is colored the same as the sandstones of the central portion of Wisconsin referred to the Potsdam. In the legend the Lake Superior sandstone is included with the lower sandstones of Wisconsin and Minnesota as the equivalent of the Potsdam sandstone of New York.

Mr. J. C. Norwood calls attention to the resemblance of the sandstone on the south shore of Lake Superior, west of Montreal River, to the sandstones of the Chippewa, St. Croix, and Kettle Rivers. A section is given that occurs above the mouth of Cranberry River.[1]

In some remarks connected with the geology of the north shore of Lake Superior Prof. J. D. Whitney states that from Sault Ste. Marie, following the south shore in its whole extent, and along the north side as far east as the northeastern extremity of Neepigon Bay, we find exposed on the lake shore only shales, sandstones, and conglomerates, the equivalent of the Potsdam sandstone and the accompanying trappean rocks.[2]

In speaking of the red sandstone of Lake Superior Mr. H. R. Schoolcraft states that in his expedition of 1820 he recognized a sandstone at the Sault of St. Mary's. He says:

> That this is the Old Red sandstone may be inferred simply from the fact that, although deposited originally in horizontal beds, its position has been disturbed in many localities.[3]

In his report as State geologist of Michigan Dr. A. Winchell describes the sandstone at the Falls of the St. Mary's River, where it has a measured thickness of at least 18 feet. On some of the surfaces he observed obscure traces of Algæ. On some specimens from the Montreal River not less than three species of fossil plants have been discovered. He favors the view that the sandstones of the south shore of Lake Superior are of the age of the Potsdam.[4]

When commenting upon the fact that Prof. Jules Marcou had referred the red sandstone of Lake Superior to the Trias Prof. J. S. Newberry states:

> No American geologist will need to be informed that the sandstones of Lake Superior are of the age of the Potsdam of New York and lie at the base of the Silurian series. It is true that there is considerable lithological resemblance between the Potsdam sandstones of Lake Superior and those overlying the Carboniferous series in New Mexico; but that fact serves simply to show how fallacious are the inferences derived alone from lithological characters.[5]

---

[1] Description of the geology of middle and western Minn., including the country adjacent to the northwest and part of the southwest shore of Lake Superior. Rep. Geol. Surv. of Wis., Iowa, and Minn., and, incidentally, of a portion of Nebraska Territory. Philadelphia, 1852, p. 269.

[2] Remarks on some points connected with the geology of the north shore of Lake Superior. Am. Assoc. Proc., vol. 9, 1855, p. 205.

[3] Observations on the geology and mineralogy of the region embracing the sources of the Mississippi River and the Great Lake basins during the expedition of 1820. Schoolcraft's Mississippi River. Phila., 1855, pp. 316, 317.

[4] Geology, general sketch. Geol. Surv. Michigan, 1st Biennial Rep. of Prog. Lansing, 1861, pp. 49–51.

[5] Geological report. Report upon the Colorado River of the West, expl. in 1857–'58 by Lieut. J. C. Ives. *Part III*, 1861, p. 75.

Of the sandstone at the base of the fossiliferous series Dr. T. S. Hunt says:

Along the northern rim of the great Paleozoic basin of North America the Potsdam sandstone of the New York geologists is unquestionably the lowest rock from below Quebec to the Island of Montreal, and thence passing up the valley of Lake Champlain and sweeping round the Adirondack Mountains until it reenters Canada and soon disappears to the north of Lake Ontario, where the Birdseye and Black River limestones repose directly upon the Laurentian rocks, and furthermore overlie the great Lake Superior group of slates and sandstones, which, reposing on the unconformable Huronian system, constitute the upper copper-bearing rocks of this region. This Lake Superior group, as Sir William Logan remarks, may then include the Potsdam, Calciferous, and Chazy, and thus be equivalent in part to the Quebec group, hereafter to be described.[1]

The section on the Montreal River, including 11,850 feet of strata, according to Mr. Charles Whittlesey, is referred by him to the Potsdam sandstone, with a statement that this is not the entire thickness of the Potsdam at the mouth of the Montreal.[2] He states that some foreign geologists have essayed to place this formation nearly at the summit of the geological system, not only without evidence but against the most conclusive proof. He correlates the sandstone at the Falls of the St. Croix, with its abundance of fossils, with the sandstone of the section mentioned, and states that it has been traced stratigraphically beneath the Trenton and Calciferous strata of the New York survey, on the St. Mary's River, at the Pictured Rocks, on the Escanawba, the Menominee, Oconto, Wolf, Wisconsin, and St. Croix Rivers.[3]

The view that the sandstones and superjacent rocks of the south shore of Lake Superior were deposited within the lake's basin when the lake stood at a higher level has been held only, as far as known to me, by Mr. Thomas Macfarlane. In a report on the geological formations of Lake Superior he says:

On the other hand, the Upper rocks and St. Mary sandstones are never found far inland, but occur close to the shore in comparatively low-lying land and rocks. They seem to have had, as the theater of their eruption and deposition, the bottom of the lake, at a time when its surface was at a higher level than it is at present, although not so high as the general surface of the surrounding Laurentian and Huronian hills.[4]

In a paper on the position of the sandstone of the southern slope of a portion of Keweenaw Point, Lake Superior, Prof. Alexander Agassiz states that the sandstone of the southern side of the mineral range in the vicinity of Torch Lake is plainly of a different age, lying, as it does, unconformably upon the former (i. e., the trap). This view agrees with that held by the geologists who refer the sandstone of the southern portion of Keweenaw Point to the Potsdam, and that of the northern coast to a pre-Potsdam formation.[5]

---

[1] On some points in American geology. Am. Jour. Sci., 3d ser., vol. 31, 1861, p. 397.

[2] The Penokie Mineral Range, Wisconsin. Bost. Soc. Nat. Hist. Proc., vol. 9, 1863, p. 238.

[3] Op. cit., p. 239.

[4] On the geological formation of Lake Superior. Canad. Naturalist, new ser., vol. 3, 1867, p. 178.

[5] On the position of the sandstone of the southern slope of a portion of Keweenaw Point, Lake Superior. Boston Soc. Nat. Hist., Proc., vol. 11, 1868, p. 245.

In an article on the age of the copper-bearing rocks of Lake Superior, Messrs. Brooks and Pumpelly refer the sandstones of the south shore to the Silurian, and state that they were deposited unconformably upon the subjacent copper-bearing rocks.[1]

In his report upon the Paleozoic rocks of Michigan, Dr. C. Rominger concludes that the Lake Superior sandstone is the equivalent of the Potsdam sandstone. He states that there is no record of any instance in which recognizable fossils were found in situ in the Lake Superior sandstone.[2] The reference of the sandstones of the western side of Keweenaw Point is based upon their lithologic resemblance to those east of the trap range along the center of the point.

In a paper on some points in the geology of northern Wisconsin Prof. R. D. Irving drew the conclusions that—

> (1) The Copper-Bearing and Huronian series were once spread out horizontally one over the other and owe their present highly tilted position to one and the same disturbance. (2) That subsequently, after a long period of erosion, the horizontal Silurian sandstones were laid down over and against the upturned edges of the Copper-Bearing series, filling also the synclinal, in Ashland County, which lies between the northward and southward dipping sandstones. (3) That hence the Copper-Bearing series is more clearly allied to the Archean than to the Silurian rocks.[3]

He describes the series of horizontal sandstones and shales that form the basement rock of the Apostle Islands and the north coast line of Ashland, Bayfield, and Douglas Counties. These he considers in every way to be the equivalent, or, which is more probable, the downward continuation of light-colored Primordial sandstone of the Mississippi Valley. They reappear farther south, on the headwaters of the St. Croix, from whence they can be traced uninterruptedly until they disappear beneath the light-colored sandstones of the Mississippi Valley.[4] This paper of Prof. Irving's was reprinted in the American Journal of Science, under the title "On the age of the copper-bearing rocks of Lake Superior," etc.[5]

It is stated by Mr. E. T. Sweet that the term "Lake Superior sandstone" "is generally employed to designate the reddish aluminous sandstones which nearly everywhere border the south shore of Lake Superior. They also form the basement rock of the Apostle Islands. They have never been found in a tilted condition."[6] He considers that Dr. Rominger, of the Michigan Geological Survey, has definitely settled that these sandstones are the downward continuation of the light-colored sandstones of the Mississippi Valley;[7] and concludes that the western sandstone of Irving, or that of the Apostle Islands and vicin-

[1] On the age of the copper-bearing rocks of Lake Superior. Am. Jour. Sci., 3d ser., vol. 3, 1872, pp. 431 432.

[2] Paleozoic rocks. Geol. Surv. Michigan, Upper Peninsula, 1869-1873. vol. 1, pt. 3, 1873, p. 80.

[3] On some points in the geology of northern Wisconsin. Wisconsin Acad. Sci. Trans., vol. 2, 1874, p. 117.

[4] Op. cit., pp. 114, 115.

[5] Am. Jour. Sci., 3d ser., vol. 8, 1874, pp. 16–56.

[6] Notes on the geology of northern Wisconsin. Wis. Acad. Sci. Trans., vol. 3, 1876, p. 48.

[7] Op. cit., p. 49.

ity, is of the same age as the eastern sandstone, along the shore of Lake Superior, east of Keweenaw Point.

A description of the Lake Superior sandstone is given by Dr. Irving in his account of the geological structure of northern Wisconsin that is very full and complete, and it will be referred to again in the summary of our present knowledge of that formation.[1] In the account of the geology of the eastern Lake Superior district in the same volume Dr. Irving described the Lake Superior or Potsdam sandstone of the Apostle Islands and adjoining shore.[2] An account of the sandstone as it occurs in the western Lake Superior district is given by Mr. E. T. Sweet in 1880.[3]

Dr. M. E. Wadsworth notes that the sandstone at Marquette rests upon the Azoic schists. That south of the Carp River, in the locality figured by Messrs. Foster and Whitney, the sandstone strata are seen to abut against and overlie the vertical edges of the quartzite.[4]

A general account of the Potsdam sandstone series is given by Dr. R. D. Irving in his article on the mineral resources of Wisconsin. Of the Lake Superior sandstone he says:

> The horizontal sandstone of the south shore of Lake Superior belongs unquestionably to this formation, though it is a matter of doubt whether the two sandstones do or ever did connect. The Lake Superior rock differs from its more southern equivalent in its red color.[5]

The sandstones at the eastern end of Lake Superior, on the St. Mary's River, were referred to the Chazy formation by Sir W. E. Logan. Dr. T. S. Hunt calls this view a speculation, which was shown to be untenable by the establishment of the Potsdam age of the sandstones overlying the quartzites of Wisconsin and in northern Michigan, where Rominger finds the upper sandstone to be overlaid by Calciferous-Chazy beds.[6]

The Eastern sandstone, or that between the Keweenaw Ridge and eastward along the south shore of Lake Superior, is well described by Dr. R. D. Irving in his account of the copper-bearing rocks of Lake Superior.[7] This is followed by a description of the western sandstone, or that occurring on the south shore of the lake, west of Keweenaw Point. An abstract of this report also appeared in the third annual report of the U. S. Geological Survey, 1883, pp. 89–188.

In an article on the age of the rocks of the northern shore of Lake Superior Dr. A. R. C. Selwyn states that he considers the trap and sandstone to be of Lower Cambrian age. He calls them all Lower Cambrian, which includes Potsdam and Primordial Silurian. He holds

[1] Geological structure of northern Wisconsin. Geol. Wisc. Surv. of 1873-'79, vol. 3, 1880, pp. 1-25.
[2] Op. cit., pp. 207-210.
[3] Lake Superior Sandstone. Geol. Wisc. Surv. of 1873-1879, vol. 3, 1880, pp. 350-352.
[4] Notes on the geology of the iron and copper districts of Lake Superior. Camb. Mus. Comp. Zoöl. Bull., vol. 7, 1880, p. 60.
[5] The mineral resources of Wisconsin. Am. Inst. Mining Eng. Trans., vol. 8, 1880, p. 489.
[6] The Geology of Lake Superior. Science, vol. 1, 1883, p. 219.
[7] U. S. Geol. Survey, Monograph, vol. 5, 1883, pp. 351-365.

that there is at present no evidence whatever on the north shore of Lake Superior of their holding any other place in the geological series.[1]

This view of Dr. Selwyn's was concurred in by Prof. J. D. Whitney, who stated it to be the opinion held by Messrs. Foster and Whitney thirty years previously.[2]

Dr. Irving took exception to the statement made by Dr. Selwyn that there is no evidence whatever of the rocks holding any other place in the geological series than that including the Potsdam and Primordial Silurian, and stated:

(1) That the copper-bearing rocks underlie unconformably, and with an immense unconformity, a series of sandstones holding Cambrian fossils. * * * (2) That the copper-bearing strata also underlie unconformably the "eastern sandstone" of the south shore of the eastern half of Lake Superior. * * * (3) That the time-gap between the copper-bearing series and the Huronian was too long to allow of our classing them together.[3]

The view of Messrs. Selwyn and Whitney was also opposed by Dr. T. S. Hunt, who referred the basal sandstone to a pre-Cambrian group.[4]

In a note on Dr. Selwyn's paper, Prof. N. H. Winchell concurs with him in the sweeping affirmation that there is at present no evidence whatever of their (i. e., the copper-bearing rocks) holding any other place in the geological series than that of the Potsdam or Primordial Silurian. "I would also add that there is incontestible evidence that they *can hold no other*."[5]

In opposition to the view of Prof. Winchell, Prof. Chamberlin stated the evidence upon which the pre-Cambrian age of the copper-bearing series of Lake Superior is based. It is (1) the general stratigraphical relation indicated. This he considers to be the weakest of all. (2) Differences in thickness; (3) differences in constitution; (4) unconformity; (5) the inherent inconsistency of the view; (6) the dynamic simplicity of the view; (7) the discovery of a like series in the Grand Cañon of the Colorado.[6]

Shortly after Prof. Chamberlin's paper, Dr. M. E. Wadsworth published an article on the relations of the Keweenawan series to the Eastern sandstones. His observations differ from those of Dr. Irving and he claims that the Keweenawan series has no existence distinct from or older than the sandstone of Potsdam age. In speaking of his observations he says, "These observations also prove at the birthplace of the Keweenawan series, that formation and the Eastern sandstone were one and the same."[7]

The paper of Dr. Wadsworth was followed shortly after by one of Messrs. Whitney and Wadsworth on the "Azoic system and its pro-

[1] Age of the rocks on the northern shore of Lake Superior. Science, vol. 1, 1883, pp. 11, 221.
[2] Geology of Lake Superior. Science, vol. 1 1883, p. 39.
[3] The copper bearing rocks of Lake Superior. Science, vol. 1, 1883, pp. 140, 141, 359, 360, 422.
[4] The Geology of Lake Superior. Science, vol. 1, 1883, pp. 218, 219.
[5] The Lake Superior Rocks. Science, vol. 1, 1883, p. 334.
[6] The copper bearing series of Lake Superior. Science, vol. 1, 1883, pp. 453–455.
[7] On the relation of the "Keweenawan series" to the Eastern sandstone in the vicinity of Torch Lake, Michigan. Boston Soc. Nat. Hist. Proc., vol. 23, 1883, p. 174.

posed subdivisions." This contains a critical review of the published papers upon the age of the copper-bearing rocks of Michigan, Wisconsin, and Canada.[1]

In their observations on the junction between the Eastern sandstone and the Keweenaw series Messrs. Irving and Chamberlin published a map of Keweenaw Point, showing the distribution of the Eastern sandstone to be confined to the southeastern side of the point, the northern and northwestern sides being formed of the Keweenaw series.[2] They discuss the views held by Messrs. Jackson, Foster and Whitney, Agassiz, Rominger, and Credner upon the stratigraphic position in the geologic series of the Eastern sandstone and the sandstones of the Keweenawan series; and give also a detailed account of the contact between the sandstone and the Keweenaw rocks.

MISSOURI.

The first notice we have of a sandstone about the Ozark Mountains of southeastern Missouri is by Dr. Edwin James in 1822, who called attention to an inclined sandstone, like that of the Alleghany Mountains, between which and the granite there intervened a stratum of clay slate highly inclined and resembling the primitive clay slate of New England.[3]

This was followed twenty-nine years later by a sketch of the geology of the State of Missouri, in which Mr. H. King describes what he calls the second magnesian limestone. Beneath this is a sandstone which he was inclined to correlate with the Potsdam sandstone of New York. The presence, however, of Lituites, Euomphalus, Pleurotomaria, Natica? was opposed to this view, but the stratigraphic and lithologic evidence sustains the correlation. In order to explain the presence of the fossils he suggests that "this may be an independent formation not represented in New York or elsewhere, and yet nearly contemporary with the first evidences of organic existence there and to be associated with them in the same geological epoch."[4]

The work of the first Missouri survey proved the presence of four magnesian limestones with a belt of sandstone between the third and the fourth, the fourth limestone forming the base of the series. Prof. G. C. Swallow describes the third sandstone, above the fourth magnesian limestone, as a white saccharoidal sandstone, made up of slightly cohering transparent globular and angular particles of silex. It is assigned a thickness of 30 feet, and owing to its position below the third magnesian limestone is considered at least as old as the Calciferous sandrock, and there is great probability that it may prove to be beneath

[1] The Azoic system and its proposed subdivisions. Harvard Mus. Comp. Zool. Bull., vol. 7, 1884, pp. 482–498.

[2] Observations on the junction between the Eastern sandstone and the Keweenaw series on Keweenaw Point, Lake Superior. U. S. Geol. Surv. Bull., No. 23, 1885, pl. i.

[3] Geological sketches of the Mississippi Valley. Phil. Acad. Sci., Jour., vol. 2, 1822, p. 329.

[4] Some remarks on the geology of the State of Missouri. Am. Assoc. Proc., vol. 5, 1851, pp. 190, 191.

the Potsdam sandstone.[1] In a foot-note on page 129 it is said that since the report was written Mr. Meek discovered a trilobite in the third magnesian limestone, which he and Dr. B. F. Shumard considered identical with one from the Potsdam sandstone of the Northwest. In the tabulation of the strata as determined in Missouri both the third sandstone, and the fourth magnesian limestone are included under Calciferous sandrock.[2]

When speaking of the geological map and the section of the rocks of Missouri, prepared prior to 1861, Prof. G. C. Swallow states that the Potsdam sandstone rests unconformably upon the Azoic stratified slates of Missouri.[3]

The presence of the third sandstone and the fourth magnesian limestone is noted by Mr. F. B. Meek in Morgan and Miller Counties. In Miller County the two formations have a thickness of 33 feet and in Morgan County the third sandstone varies from 15 to 30 feet. The fourth magnesian limestone is assigned a thickness of 150 feet.[4]

On the map of Madison County, prepared by Messrs. C. J. Norwood and G. C. Broadhead, the geographic distribution of the rocks referred to the Cambrian and pre-Cambrian is delineated.[5]

Below the third magnesian limestone in Madison, St. Francois, and Iron Counties, Prof. G. C. Broadhead found siliceous or gritstone beds with intercalated magnesian limestones and subjacent to these are marble beds, beneath which occur sandstones, conglomerates, and shales. These are numbered one, two, and three, respectively. In No. 3, beneath the third magnesian limestone, *Lingulella lamborni*, Meek occurs. On the St. Francois River, in Madison County, the lower unaltered sandstones rest directly on the granite.[6]

At a deep well at the St. Louis County Insane Asylum the following section is referred to as beneath the third magnesian limestone:

11. 98 feet of third sandstone.
12. 384 feet of fourth magnesian limestone.
13. 54 feet of Potsdam sandstone.
14. 245·4 feet, mostly granite, although a portion of the upper part may be sandstone.
15. 40 feet of granite.[7]

A more detailed account of the strata beneath the third magnesian limestone is given on pages 352–357. The fossiliferous bed is separated as a "Lingula grit." In this there were observed *Lingulella lamborni*,

[1] Geology of Missouri. Silurian System. Geol. Surv. Missouri; 1st and 2d ann. repts., part I, 1855, pp. 128, 129.

[2] Op. cit., pls. between pp. 60 and 61.

[3] Remarks on the Geological Map and Section of the rocks of Missouri. Am. Nat., vol. 5, 1871, p. 541.

[4] Reports on the geological survey of the State of Missouri, 1855 1871, 1873, pp. 127, 149.

[5] Atlas accompanying Geological Survey of Missouri, Report, including field work of 1873-1874, vol. 1. Jefferson City, 1874.

[6] Op. cit., p. 31.

[7] Op. cit., p., 32.

Orthoceras, a gasteropod, and a form resembling a cross-section of a coral of the genus Zaphrentis.

In a description of the southeast Missouri lead district Prof. Broadhead gives a résumé of the geology, and suggests that if the *Lingula* (*Lingulella*) *lamborni* and Scolithus should be found in the Calciferous group he would prefer to assign all the rocks from the lower sandstone to No. 1, inclusive, as Calciferous.[1] The marble of southeastern Missouri was referred in 1882 by Prof. Broadhead to the older series or Potsdam, and the upper series to the Upper Silurian, with the statement that Potsdam quarries are found in Madison, Iron, and Reynolds counties. The marble beds will be spoken of in the summary of the Cambrian rocks of Missouri.[2]

In a paper upon "The Geological History of the Ozark Uplift" Prof. G. C. Broadhead describes, in 1889,[3] in a general way rocks referred to the Potsdam and the Calciferous formations. Of these he says:

> The evidence is that the sandstones and magnesian limestones (Potsdam and Calciferous) were deposited in Archean valleys of erosion, for they generally repose nearly horizontally, or with slight inclination, upon the Archean.[4]

EASTERN BORDER OR ADIRONDACK SUB-PROVINCE.

This includes the area about the Adirondack Mountains of New York and the adjoining portions of Canada to the north.

In a report of the geological structure of the county of Saratoga, Mr. J. H. Steele states that a conglomerated mass of rock is found in the town of Greenfield not far from its south line, on the southeast side of the Kayadarosseras Mountains, resting upon the primitive rocks. He says:

> It consists of rounded pebbles of quartz, from the size of a small shot to that of a man's head, united into one common mass by a kind of coarse ferruginous sand. It extends along the mountains to no great distance, but fragments of it lay scattered in all directions, and, indeed, are found along the whole extent of the south line of the town of Greenfield, and in various other places.[5]

Under the heading of "Coarse Siliceous sandstone" a description is given of an extended horizontal stratum along the west part of the north line of the town of Saratoga Springs, and some way into the town of Greenfield:

> It is a coarse, hard rock, resembling common quartz in its fracture, but it is more loose and granular in its structure. It is of a white color, and when heated and thrown into water, crumbles into a fine white sand. * * * I have been somewhat at a loss to know where to place this formation, but from several circumstances I am confident it should be placed among the oldest of the transition class.[6]

---

[1] The Southeastern Missouri lead district. Am. Inst. Mining. Eng., Trans., vol. 5, 1877, p. 102.

[2] Marble of southeast Missouri. Kansas City Review, vol. 5, 1882, pp. 524 526.

[3] Am. Geologist, vol. 3, 1889, pp. 6 13.

[4] Op. cit., p. 8.

[5] A report of the geological structure of the county of Saratoga. Memoirs of the Board of Agriculture of the State of New York, vol. 2, 1823, p. 53.

[6] Op. cit., p. 54.

A description is also given of a Calcareous sandstone as it occurs on the west side of the Kayadarosseras Mountains.[1] The sandstone referred to by Mr. Steele, and also the lower portion of the Calcareous sandstone, are now known to be of Upper Cambrian age.

Various references are made by Prof. Amos Eaton to the Calciferous sandrock (or Transition sandrock) as examined by him in the valley of the Mohawk. He also says: "Perhaps the Transition sandstone of the Green Mountain series may not be connected with that of the Macomb Mountain series."[2] Most of Prof. Eaton's references to this formation are very indefinite, and he included it with the Calciferous sandrock, as exposed at Little Falls in the valley of the Mohawk. That he was aware of its stratigraphic position is shown by the comparisons made between the Transition sandstone of the Green Mountains and that of the Macomb Mountains, the latter now being known as the Adirondacks.

The attention of Mr. J. H. Steele was called to the oolitic formation about 2 miles from the village of Saratoga Springs. He described the occurrence of great quantities of calcareous concretions of a most singular structure; they are mostly hemispherical, but many of them are globular and vary in size from half an inch to that of 2 feet in diameter; they are obviously composed of a series of successive layers, nearly parallel and perfectly concentric, etc.[3] This is the first notice of a fossil that was subsequently described by Prof. James Hall as *Cryptozoon proliferum*.[4] It occurs in layers in which the Upper Cambrian or Dikelocephalus fauna is found a few miles west of Saratoga Springs.

In the first annual report of the geological survey of New York Dr. Emmons mentions a sandstone resting on the primitive rocks both on the Lake Champlain side of the Adirondack Mountains, at Whitehall, and on the western side, in the vicinity of Theresa, on the Indian River.[5] In this preliminary paper the Calciferous sandrock of Prof. Eaton and the subjacent sandstone are not clearly differentiated. In the second report, however, he separated the sandstone as the "sandstone of Potsdam."[6] His description of the rock is as follows:

> I shall not enter upon its geological relations any further than to state that in Potsdam and other towns in which it appears it uniformly rests on the primary strata; and in no part of the county is there any rock which interposes itself between it and the Primary, so that it appears here as the oldest representative of the transition series. The identification of this rock with the sandstones along the southern border of Lake Ontario will be a matter of some difficulty. It is geologically below

[1] Op. cit., p. 56.

[2] A geological and agricultural survey of the district adjoining the Erie Canal, 1824, p. 78.

[3] A description of the oolitic formation lately discovered in the county of Saratoga and State of New York. Am. Jour. Sci., vol. 9, 1825, p. 17.

[4] Cryptozoon, n. g., Cryptozoon proliferum, n. sp. Description of Pl. VI, 36th Ann. Rep. N. Y. State Mus. Nat. Hist., 1884.

[5] First annual report of the second geological district of New York. First annual report of the geological survey of New York. Albany, 1837, pp. 106, 107.

[6] Report of the geologist of the second geological district of New York. Second annual report of *the geological* survey of New York. Albany, 1838, p. 214.

the transition limestone and never in the northern district alternates with it, but always holds the relation of an inferior rock.[1]

This rock is a true sandstone, of red, yellowish red, gray, and grayish white colors. It is made up of grains of sand and held together without a cement. Intermixed with the siliceous grains are finer particles of a yellowish feldspar, which do not essentially change the character of the sandstone, but they show the probable source from which materials forming it were originally derived, viz, some of the varieties of granite. Unlike, however, most of the sandstones, it is destitute of scales of mica. The coloring matter of the rock is evidently oxide of iron, but unequally diffused through it, giving it intensity or deepness of color in proportion to its quantity. In some places it is almost wanting, which makes it, when pulverized, a good material for glass. The grains and particles in its composition are generally angular, but where it takes the character of a conglomerate, as it does in the inferior layers, they are frequently rounded. The thicker strata exhibit an obscurely striped appearance, owing to prevalence of certain colors in the different layers.[2]

In the description of the sandstone on the Lake Champlain side in Essex County it is said:

This I consider the same formation I have described under the name of the "Potsdam sandstone." Its position is evidently beneath the Transition limestone and Calciferous sandrock. It is very deficient in organic relics, though not entirely destitute of them. It is unnecessary to repeat what has already been said of this rock; it is purely quartzose or siliceous in its composition and finely stratified. It dips to the northeast at Port Kent, at an angle varying from 5° to 10°. The places where it occurs along Lake Champlain are indicated on the map of a part of this county, to which I refer the reader. This rock at Keeseville has been rent in the most remarkable manner; several fissures, the principal one of which extends nearly a mile, and through which the Au Sable flows, have been opened by some convulsion in nature to the depth in some pla·es of 100 feet, and from 5 to 20 feet wide. Near the bottom of the fissure at the High Bridge, as it is called, I discovered numerous specimens of a small bivalve mollusca, a Lingula. I found also, on examination, that the same fossil occurred through an extent of seventy feet at least, and so far as I could discover it was the only fossil inclosed in the rock. It is extremely thin and delicate, yet the shell is perfectly preserved, and is probably one of the oldest inhabitants of the globe, as the rock in which they occur is the oldest of the transition series.[3]

In the second annual report of the paleontological department of the New York survey Prof. T. A. Conrad tabulated the formations to show the order of superposition and some characteristic fossils in the transition strata. On the primary occurs No. 1, formed of variegated sandstones (Potsdam sandstone of Emmons), and the olive sandstones and slates, characterized by *Fucoides serra*. These are classified under the Cambrian system of Prof. Sedgwick.

The base of the Lower Silurian is a gray calcareous sandstone, characterized by *Lingula acuminata*. This part of his table is as follows:[4]

LOWER SILURIAN STRATA.

Gray calcareous sandstone	*Lingula acuminata*

[1] Op. cit., p. 214.
[2] Op. cit., p. 215.
[3] Op. cit., p. 230.
[4] Second annual report of the paleontological department of the survey. Third annual report of the geological survey of New York. Albany, 1839, p. 63.

CAMBRIAN SYSTEM (SEDGWICK).

1. { Olive sandstone and slate.....*Fucoides serra* (Brong.)
   { Variegated sandstone (Potsdam sandstone of Emmons).....*Dictyolites radians*

A description of the geographic distribution of the Potsdam sandstone in Clinton County is given by Dr. Emmons in the third annual report of the New York State survey. He also describes its stratigraphic character and appearance, and states that at Flat Rock the sandstone is more or less a conglomerate and coarser than at Potsdam or Keeseville.[1]

A description of the Potsdam sandstone as it occurs on the western side of the Adirondacks, in Jefferson County, is given by Dr. Emmons in his fourth annual report, as follows:[2]

Lying unconformably upon the primary is the Potsdam sandstone. It is therefore next in the series. It is a firmer rock, more crystalline, and less porous than the same rock in St. Lawrence, and especially that belonging to Potsdam.

The only fossil found in it was a small linguloid shell called *Lingula ovata*.[3]

The presence of the Potsdam sandstone in Lewis County is noted by Mr. Lardner Vanuxem, who states that the sandstone appears in the northeastern part of the county in low ridges, with all the characteristics given by Prof. Emmons, in whose district it is an extensive rock.[4]

The Potsdam sandstone as it occurs in Washington County, upon the eastern side of the mountains, is described by Dr. W. W. Mather as a hard, siliceous sandstone, white, red, gray, yellowish, and frequently striped.[5] It is well developed at Whitehall, where it has a thickness of 150 to 200 feet. It extends up the valley of Wood Creek in a southerly direction by Comstock's Landing, 1 mile east of Fort Ann, and so on farther south, diminishing in thickness and becoming interlaminated with finer-grained strata of grits, slates, and shales. Some of the strata of this rock are covered with the most beautifully characterized ripple-marks, as perfect as if just formed on the sand of a sea beach, while the rock is of the most indurated kind of sandstone.[6]

The only fossils noticed were fucoidal impressions.

The geographic distribution of the Potsdam sandstone about the Adirondacks is shown on the map of 1844 that accompanies the final report of the State geologists of New York. On a geological map of the Middle and Western States by Prof. James Hall[7] the main geographic distribution is indicated and a small area on the southern side of the Wisconsin River in Wisconsin is the same tint as the Potsdam area of New York

[1] Third annual report of the second geological district. Third annual report of the geological survey of New York, 1839, pp. 231, 232.

[2] Fourth annual report of the survey of the second geological district of New York. Fourth annual report of the geological survey of New York. Albany, 1840, p. 322.

[3] Op. cit., p. 323.

[4] Fourth annual report of the geological survey of the 3d district. Fourth Report of the Geological Survey of New York. Albany, 1840, pp. 363, 368.

[5] Fifth annual report on the geological survey of the 1st geological district. Fifth Annual Report of the Geological Survey of New York, 1841, p. 102.

[6] *Geological map of the Middle and Western States.* Geol. of New York. Report on the Fourth Geol. district, Albany, 1843.

In a tabulation of the Lower Silurian strata of the State of New York, published in 1842, Prof. T. A. Conrad states that the Cambrian system has proved to be the Lower Silurian, and he places the Potsdam sandstone at the base of the latter system, beneath the Calciferous sandstone.[1]

The final report of the geology of the second geological district contains a summary by Dr. Emmons of the characters of the Potsdam sandstone as found in the counties of Warren, Essex, Clinton, Franklin, St. Lawrence, and Jefferson, and also gives details of the formation as found in each county.[2] A description of the formation in detail and also a general descriptive summary of the formation is given by Mr. Lardner Vanuxem as it occurs in his district,[3] and Dr. W. W. Mather describes it as it occurs in Washington County and in Saratoga County.[4] Prof. James Hall describes it concisely in an account of the rocks of New York State. In its geographic distribution the rock is known in Canada, on Lake Superior, and, from its position, it is probably the same that appears on the Mississippi River mentioned by Dr. Owen in the report on the lead region of the northwest.[5] He also identifies it with No. 1 of the Pennsylvania survey, or a sandstone extending through New Jersey, Pennsylvania, and Virginia.[6]

In the account of his travels in North America Sir Charles Lyell describes the Potsdam sandstone as he saw it at Au Sable Chasm, near Keeseville, Essex County, New York. He speaks of it as a siliceous sandstone:

> In many places, this most ancient of the fossiliferous rocks of New York (the Potsdam sandstone) is divided into laminæ by the remains of innumerable shells of the genus *Lingula*. They are in such profusion as to form black seams like mica, for which they were at first mistaken. With the Lingula occurs another placunoid shell allied to, if not identical, according to Prof. E. Forbes, with a fossil which occurs in company with a small Lingula in the lowest beds of the English Silurian series at Builth, in Brecknockshire.[7]

A general account of the Potsdam sandstone is given by Dr. E. Emmons in the Agriculture of New York. It is an excellent summary of the general characters of the formation.[8]

The Potsdam sandstone of Lewis County is described by Mr. F. B. Hough in a general manner. He states that it thins out to an unimportant stratum as compared with the formation in St. Lawrence County; also that the superjacent Calciferous sandrock is represented by only a

---

[1] Observations on the Silurian and Devonian systems of the United States, with descriptions of new organic remains. Phila. Acad. Sci. Jour., vol. 8, 1842, pp. 229, 230.

[2] Geology of New York, part 2, second geological (northern) district, pp. 102–105, 177–179, etc.

[3] Geology of New York, part 3, third geological (central) district, Albany 1842, pp. 28, 29.

[4] Geology of New York; geology of the first (southeastern) district. Albany, 1843, p. 418.

[5] Geology of New York; geology of the fourth (western) geological district. Albany, 1843, p. 27.

[6] Op. cit., p. 28.

[7] Travels in North America. New York, 1845, vol. 2, pp. 131, 132.

[8] Agriculture of New York, vol. 1, 1846, pp. 117, 118.

thin layer of the fucoidal sandstone.[1] In 1850 he called attention to cylindrical masses from 3 inches to 15 and 20 feet in diameter that occur in the Potsdam sandstone near Somerville, St. Lawrence County.[2]

The description and accompanying figure recall the *Cryptozoon proliferum* described by Prof. Hall from the Potsdam formation of Saratoga County. A year later attention was again called by Mr. Hough to the cylindrical masses.[3] They are described as vertical cylinders from 2 inches to 20 feet and upward in diameter, and show a concentric structure. Numerous smaller bodies, not larger than an orange, of a spheroidal structure are also met with in the vicinity. No traces of organic life were observed in the matrix. It is evident that these bodies are unlike the Saratoga Cryptozoon.

A more extended definition of the Potsdam sandstone was given by Dr. E. Emmons in 1856. He then included with it the lower sandstone of the upper Mississippi Valley, and No. 1 of the Pennsylvania survey.[4]

An excellent summary of the existing knowledge of the Potsdam sandstone was given by Dr. J. J. Bigsby in 1858 in a paper on the Paleozoic Basin of the State of New York. A description is given of the mineral characters, mode of transition, stratigraphic position, mode of occurrence, thickness, and paleontologic character.[5]

In a tabulation of the succession of sedimentary rocks Prof. Richard Owen states that the Potsdam sandstone of New York geologists is considered by some English writers as belonging to a separate system, the Cambrian.[6]

The presence of the peculiar cylindrical masses in the Potsdam sandstone mentioned by Mr. Hough is also noticed by Mr. T. G. B. Lloyd in Jefferson County,[7] but without any attempt to explain their origin or nature.

In a note on the geology of Port Henry, New York, Dr. T. S. Hunt states that the Potsdam sandstone and the basal member of the overlying Paleozoic series is well seen in a railway cut near Port Henry. The lower beds are massive and compact, dark bluish or iron gray, with lighter bands and thin, blackish, shaly layers. The only fossils observed were *Scolithus linearis* and *S. canadensis* of the Potsdam of the Ottawa Basin.[8]

---

[1] Observations on the geology of Lewis County, New York. Am. Jour. Sci. and Agric., vol. 5, 1847, p. 273.

[2] Catalogue of mineralogical and geological specimens received from F. B. Hough, 3d Annual Rep. of Regts. Univ. State Cab. Nat. Hist, 1850, pp. 32, 33.

[3] On the cylindrical structure observed in Potsdam sandstone. Am. Assoc. Proc., vol. 4, 1851, pp. 352–354.

[4] American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. Albany, 1856, vol. 1, pt. 2, pp. 128–132.

[5] On the Paleozoic Basin of the State of New York. Part I. A synoptical view of the mineralogical and fossil characters of the Paleozoic strata of the State of New York. Quart. Jour. Geol. Soc., London, vol. 14, 1858, pp. 338, 339.

[6] Preliminary observations; general report and description by counties. (Lower and Upper Silurian). Geological reconnaissance of Indiana, made in 1859–'60. Indianapolis, 1862, p. 14.

[7] Geological notes from the State of New York. Quart. Jour. Geol. Soc., London, vol. 32, 1876, pp. 78, 79.

[8] The geology of Port Henry, New York. Canadian Nat., new ser., vol. 10, 1883, p. 421.

A short notice of the discovery of a massive limestone superjacent to the typical Potsdam sandstone containing species of the Potsdam fauna equivalent to the fauna of the upper horizon of the lower sandstone of the Mississippi Valley was made by Mr. C. D. Walcott in 1884. The limestone was originally referred to the Calciferous formation.[1]

Mention is made of the contact between the Potsdam sandstone and the subjacent pre-Cambrian rocks in the vicinity of Fort Ann, Washington County, New York, by Mr. C. E. Hall.[2]

A section of the Potsdam sandstone with the superjacent limestone, carrying the Upper Cambrian fauna was published by Mr. C. D. Walcott in 1886 accompanied by a list of the fossils found and a comparison of them with the Wisconsin fauna referred to the Potsdam by Prof. James Hall.[3]

In the fifth annual report of the State geologist of New York, in some field notes on the geology of the Mohawk Valley, with a map, Messrs. C. E. Beecher and C. E. Hall describe a section that occurs in a cut on the West Shore Railroad at "Little Nose, Randall, Montgomery County, New York."[4] In the woodcut illustrating the section, a breccia that occurs unconformably beneath the Calciferous sandrock is stated to contain Potsdam sandstone, crystalline limestone, quartzite, etc. The evidence upon which the fragments of sandstone were identified as of Potsdam age is not given.

In a paper on a great Primordial quartzite Prof. N. H. Winchell republishes a description of the Potsdam sandstone by Dr. Emmons and correlates the formation with the "granular quartz" of the western slope of the Green Mountains and the pre-Cambrian quartzites of Wisconsin and Minnesota.[5]

In a paper read before the Geological Society of America, at Washington, D. C., December 31, 1890, Messrs. N. S. Shaler and H. S. Williams described the presence of a thin bed of shale beneath the Calciferous sandrock and just above a thin bed of sandstone that rests unconformably upon the subjacent pre-Paleozoic rocks. The locality is a quarry at Little Falls. In the shale numerous specimens of *Lingulepis acuminata* were found.[6]

CANADIAN EXTENSION.

In a report of progress of the geological survey of Canada for 1845–'46 Sir W. E. Logan notes the presence of a sandstone in the Ottawa district, but is doubtful whether it represents the Potsdam sandstone, as

[1] Potsdam fauna at Saratoga, New York. Science, vol. 3, 1884, pp. 136, 137.

[2] Laurentian Magnetic iron ore deposits from northern New York, accompanied by a geological map of Essex County. Report of the State geologist for the year 1884. Albany, 1885, p. 32.

[3] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 21, 22.

[4] Fifth Ann. Rept. State Geologist of N. Y., for 1885. Albany, 1886, p. 10.

[5] A Great Primordial Quartzite. Am. Geol., vol. 1, 1888, pp. 173–178.

[6] Unpublished.

it may be in the lower beds of the Calciferous.[1] In a later report he noted the presence of the Potsdam sandstone on the north shore of the St. Lawrence at Murray's Bay, 90 miles below Montreal, describing it as a formation consisting of white, translucent, slaty quartz-rock having an exposed thickness of 45 feet and conformably subjacent to the Calciferous sandrock.[2]

A brief summary of the lithologic and paleontologic characters of the Potsdam sandstones in Canada was read by Dr. T. S. Hunt before the American Association for the Advancement of Science in 1851.[3]

In an extended paper on the foot-prints occurring in the Potsdam sandstone of Canada, Sir W. E. Logan describes the Potsdam sandstone as it occurs in Canada in the St. Lawrence Valley. He states that—

> The sandstone in Beauharnois County and the neighboring part of the State of New York is from 300 to 700 feet thick. In the lower part it contains many beds of conglomerate, with quartz pebbles, and it has some red layers; but towards the top it becomes a fine-grained, hard, white sandstone, and at the summit it is interstratified with calcareous layers, forming a passage to the rock which overlies it.[4]

The description of the extention of the Potsdam sandstone between the River of the North and Beauharnois was continued by Sir W. E. Logan in the report for 1851–'52.[5] In the same volume Dr. Alexander Murray describes the sandstone along the shores of the St. Lawrence in the vicinity of Brockville, and also in the outcrops exposed between the rivers Ottawa and St. Lawrence.[6]

This was followed in 1854 by the account of Dr. Murray's exploration between Kingston and Lake Simcoe. In this region the Potsdam is not largely developed, the greatest thickness of it observed in any one place being certainly not over 40 or 50 feet, while west of Knowlton Lake, in Loughborough, it appears gradually to decrease in thickness, and eventually to die out altogether.[7]

In the summary of the work of the Geological Survey of Canada from its commencement to 1863, there is given a very complete description of the stratigraphic, lithologic, and paleontologic characters of the Potsdam sandstone as known in Canada.[8] Since that time very little has been published upon the formation.

---

[1] Report on sequence and distribution of the formations (on the Ottawa). Geol. Surv. Canada: Report of progress for 1845–'46, Montreal, 1847, p. 51.

[2] Report on Bay St. Paul and Murray Bay. Geol. Surv. Canada: Report of progress for 1848–'49. Toronto, 1850, pp. 10, 11.

[3] Remarks on the lithological and paleontological characters of the Potsdam sandstone. Am. Assoc. Proc., vol. 6, 1852, pp. 272–273.

[4] On the foot-prints occurring in the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc., Lond., vol. 8, 1852, p. 200.

[5] Report [on country between Riviere du Nord and Beauharnois] Geol. Surv. Canada, 1851–'52. 1852. pp. 8–14.

[6] Report [of country lying between rivers Ottawa and St. Lawrence] Geol. Survey of Canada for 1851–'52, 1852, pp. 64–67.

[7] [Exploration between Kingston and Lake Simcoe.] Geol. Surv. Canada: Report of progress for 1852–'53, 1854, p. 109.

[8] Geological Survey of Canada: Report of progress from its commencement to 1863. Montreal, 1863, pp. 87–109.

WESTERN BORDER OR ROCKY MOUNTAIN SUBPROVINCE.

This subprovince includes central Colorado, central and northern Wyoming, South Dakota and southern central Montana.

COLORADO.

The probable presence of the equivalent of the Potsdam sandstone of the Mississippi Valley in the Colorado range was noticed by Dr. F. V. Hayden in 1874. He says:

The lowest beds of sedimentary rocks are rather coarse sandstones, and conglomerate made up of water-worn quartz pebbles, with very irregular laminæ of deposition, the whole reminding one of the Potsdam group. * * * There is considerable variety in the aggregate of beds here, which may be regarded as Silurian, and we may conclude that the Potsdam group is quite well represented, and that it is possible that some of the higher divisions occur. These rocks require a still more careful study, yet it is an interesting fact to know of their existence in this locality. In the lower sandstones I found a species of Lingula, the present season, probably a Potsdam form.[1]

These observations were made along William's Cañon, 2 or 3 miles above Colorado Springs. Of the probable presence of the "Potsdam" in the South Park, on the north slope of Mount Lincoln, and on all of the surrounding high mountains he does not appear to have any doubt. He says:

Before going further I will state what I believe to be the age of all the limestones and quartzites which seem to cover the highest mountains, and in which most of the valuable mines are found. I think there is no doubt that they belong to the Potsdam group, though I was unable to discover any fossils. Dr. Peale found a few obscure forms which indicated that the group is of the same age as those next to the granites in Utah, which we now know are of that age.[2]

While studying the geology from Denver to Colorado Springs, Dr. A. C. Peale examined and measured a number of sections passing from various horizons in the superjacent rocks to the Archean. In one, extending from Glen Eyrie eastward to Camp Creek, there are 40 feet of coarse sandstone of a grayish white, dark green, gray and brick red color. This series rests upon the granite; is beneath limestones referred to the Quebec group, and is considered to represent the Potsdam group.[3]

On Trout Creek, in Bergen Park, 93 feet of sandstone is referred to the Potsdam.[4] In a reddish sandstone superjacent to the "Potsdam" a number of fossils were found that were referred to the Quebec group. As now known this fauna is of Lower Silurian (Ordovician) age, corresponding to the Calciferous zone of the New York section. Another section was measured on one of the eastern tributaries of Trout Creek,

[1] Report of F. V. Hayden, U. S. Geologist. U. S. Geol. Surv. of the Terr., 7th Ann. Rep., 1874, p. 35.
[2] Op. cit., p. 41.
[3] Report of A. C. Peale, M. D., geologist of the South Park Division. U. S. Geol. Surv. of the Terr., 7th Ann. Rep., 1874, p. 202.
[4] Op. cit., p. 208.

in which 67 feet of sandstone occur resting upon the granite. Of these sections Dr. Peale says:

A comparison of the sections given above shows that the Potsdam group is represented by sandstones having a thickness of from 60 to 80 feet, while the beds that represent the Quebec group are a little over 100 feet thick.[1]

References to the sandstone supposed to be Potsdam are also found on pages 226, 236, 242, and 255.

During the field season of 1874 Dr. A. C. Peale found on Eagle River a series of beds resting on the gneiss and schist. From their position and lithologic relations to corresponding beds seen in the Colorado Range in 1873 the lower layers are referred to the Potsdam group. It is represented by a bed of white quartzite.[2]

A reference to the probable occurrence of the Potsdam horizon upon the eastern side of the Colorado Range is made by Mr. Arnold Hague, in his general description of the geology of the range. From the fact that a sandstone occurs in the Black Hills, and contains fossils of a Primordial type, he thinks the sandstone occupying a similar stratigraphic position in the Colorado Range will be found to contain the same fauna.[3]

On the geological map of Colorado, published by Dr. Hayden in 1877, the quartzite and the limestone referred to the Potsdam series are included with the Silurian, and their geographic distribution is merged with the latter on the map.

In his synopsis of the geological formations found in Colorado Dr. F. M. Endlich tabulates the localities and formation of the "Potsdam group."[4]

When describing the Paleozoic rocks of the Mosquito Range in central Colorado, Mr. S. F. Emmons states that the Cambrian is represented by quartzites passing gradually upward into calcareous shales, with limestones of probably Silurian age above, the aggregate thickness of the two being about 400 feet.[5] In the tabulation of the Mosquito section the Cambrian white quartzite is given a thickness of from 150 to 200 feet before passing into calcareous and argillaceous shales above.[6] The only fossil remains found in this series occur in a bed of greenish chloritic slates on the east flank of Quandary Peak, about a mile above the Monte Cristo mine. They belong to the genus Dikelocephalus and resemble closely *Dikelocephalus minnesotensis* of the Potsdam formation. From analogy with other sections Mr. Emmons thinks it safe to assume that the fossiliferous shales occur above the main body of quartzite and near the base of the transition series.[7]

---

[1] Op. cit., p. 209.

[2] Report on Middle Division. (Stratigraphy-Paleozoic formations). U. S. Geol. and Geog. Survey of the Terr., Ann. Rep. for 1874, 1876, pp. 110, 111.

[3] Hague, Arnold, and S. F. Emmons. Descriptive geology U. S. Geol. Expl. of the Fortieth Par.; Clarence King, vol. 2, 1877, p. 29.

[4] Report of F. M. Endlich, geologist of the White River Division. U. S. Geol. Surv. of the Ter., 10th Ann. Rep., 1878, p. 130.

[5] Geology and mining industry of Leadville, Colorado. Mon. U. S. Geol. Survey, vol. 12, 1886, p. 55.

[6] Op. cit., p. 57.

[7] Op. cit., p. 60.

WYOMING.

As geologist to Capt. Reynold's expedition to the headwaters of the Missouri and Yellowstone Rivers, Dr. F. V. Hayden identified, in 1861, the fossiliferous "Potsdam" sandstone of the Black Hills, and considered a sandstone holding the same relative position and exhibiting the same lithologic characters on the slopes of the Big Horn Range as the same formation. It is further stated that "a few thin layers of fine calcareous sandstone were observed filled with fossils characteristic of this period."[1]

From the Big Horn Range he crossed to the Laramie Range. At the head of the La Bonté Creek he noticed a bed resting discordantly upon Azoic slates 50 to 100 feet in thickness, holding the same position and possessing the same lithologic characters it reveals at other localities.

I could discover no fossils in it at this point, but I am confident that this bed represents the Potsdam sandstone. This rock (the Potsdam) is more or less changed by heat from beneath, but I was able to trace it continuously from the source of the Chugwater Creek to the source of Cache la Poudre, a distance of over 100 miles. It was also seen along the eastern slope of the Wind River Mountains, but did not contain any organic remains.[2]

A more extended account of the character of the Primordial sandstone of the Rocky Mountains was published by Dr. Hayden in 1862.[3] It is accompanied by a description of the species of fossils found in the Black Hills and the Big Horn Mountains and further reference to it will be found in the account of the Cambrian rocks of Wyoming.

All of the essential part of Dr. Hayden's article of 1861 was reprinted in an article on the Geology and Natural History of the Upper Missouri, which appeared in 1863.[4] This essay is, as stated by the author, the substance of a geological report made by him to Capt. Raynolds on the exploration of the Yellowstone and Missouri Rivers. The latter report was issued in 1869, accompanied by a large map, dated 1859–'60, upon which the geographic distribution of the formations identified by Dr. Hayden are delineated. Within the present area of Wyoming a narrow belt of the "Potsdam" sandstone is represented as entirely surrounding the Big Horn Mountains, and as forming a continuous band with that along the eastern side of the Wind River Range and an interrupted belt on the western side of the latter range. The two mountains now known as the Wyoming Mountains also had a narrow band of "Potsdam" sandstone about them. To the north this band is represented as continuing westward across the Big Horn River, then north on the western side of the Yellowstone Lake region as far north as Beaver River, where it is interrupted. Several mountains directly north

[1] Sketch of the geology of the country about the headwaters of the Missouri and Yellowstone Rivers Am. Jour. Sci., 2d ser., vol. 31, 1861, p. 234.

[2] Op. cit., p. 234.

[3] The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci. 2d ser., vol. 33, 1862, pp. 68-79. Canadian Jour., new ser., vol. 7, 1862, pp. 149-151.

[4] On the Geology and Natural History of the Upper Missouri. Am. Philos. Soc. Trans., vol. 12, new ser., 1863, pp. 1-218.

of the Yellowstone Lake region are represented as surrounded by the same formation.[1]

At the South Pass of the Wind River Mountains Dr. Hayden found the granites occupying a very restricted area and extending from them a large thickness of "Potsdam" sandstone containing *Obolella nana* and a Lingula.[2]

Prof. F. H. Bradley in 1873 identified the "Quebec group" by the presence of Conocoryphe and Dikelocephalus in limestones upon the flanks of the Teton range of mountains. At one of the outcrops of these limestones "they are immediately underlaid by about 300 feet of partly compact, partly shaly, glauconitic sandstones, which are evidently equivalent to the so-called Knox sandstones of Safford, which form in Tennessee, the lower part of the Quebec group. No fossils were seen in these beds. They are apparently unequally distributed, since no corresponding beds appear along the cañon of West Teton Creek. Beneath them, and often present when they are absent, we generally find from 50 to 75 feet of a very compact ferruginous quartzite which must represent the Potsdam, though this also, is sometimes wanting."[3] In a diagram of a section extending from Henry's Fork through the Teton Mountains the so-called Quebec group and Potsdam quartzite are represented on each side of the range, the quartzite resting directly on the granite.[4]

The preliminary paleontological report of Mr. F. B. Meek refers the beds containing fragments of Conocoryphe and Dikelocephalus, found on the west base of Big Horn Mountains by the Hayden survey in 1872, to the Potsdam or Primordial zone.[5]

In speaking of the Paleozoic rocks of the Laramie Hills, Mr. Arnold Hague states that all paleontologic evidence obtained from these beds would tend to show that they belong to the Coal Measure limestone.[6]

The strata along the eastern slope of the Wind River Mountains referred to the Potsdam by Dr. Hayden were studied by Prof. T. B. Comstock while geologist of Capt. W. A. Jones's expedition to northwestern Wyoming. He found the sandstone closely resembled that described by Prof. J. D. Whitney in Wisconsin. The local peculiarities of this sandstone and its associated rocks as described in the Mississippi Valley and New York are strikingly repeated in the Rocky Mountain region. The greatest thickness of the sandstone in the region of the

[1] Geological report of the Exploration of the Yellowstone and Missouri Rivers. Under the direction of Capt. W. F. Raynolds, 1859–'60, Washington, 1869, p. 144, map.

[2] Report of F. V. Hayden (on the geological survey of Wyoming.) U. S. Geol. Surv. of the Terr., 4th Ann. Rep., 1871, p. 33.

[3] Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 216.

[4] Op. cit., p. 218.

[5] Preliminary paleontological report . . . with remarks on the ages of the rocks, etc. U. S. Geol. Survey of the Territories, embracing portions of Montana, Idaho, Wyoming, and Utah; 6th Ann. Rep. 1873, p. 431.

[6] Descriptive geology, U. S. Geol. Expl. of the Fortieth Par.; Clarence King, vol. 2, p. 76. Washington, 1877.

Wind River Mountains is about 200 feet. All the beds bear evidence of deposition in shallow seas or upon beaches or sand flats.[1]

Under the head of Quebec group, Prof. Comstock describes some calciferous layers and dolomitic limestones that are conformably superjacent to the sandstone. In them he found a species of Theca?, a trilobite of the genus Dikelocephalus and *Orthis tritonia*? Fragments of other fossils too imperfectly preserved for identification were found.[2]

If the identifications by Prof. Comstock of the species found in the limestone are correct, that portion of the limestone containing them must be referred to the Upper Cambrian zone. On the map accompanying the report the "Potsdam" formation is represented along the entire eastern margin of the Wind River Mountains and along the western central portion of the range. A narrow belt of it surrounds Creek Mountain in the northeast of the Snake Indian Reservation, and the Wyoming Mountains to the northwest of the Wind River Range.

The southern portion of the Sweetwater district in the Wind River Range was visited by Dr. F. M. Endlich in 1877. He found a Lingula, probably *Lingula prima*, and estimated the thickness of the entire series as varying between 180 and 320 feet.[3] He refers to the Calciferous group a thin series of sharply bedded strata composed of blue limestones and blue and yellow dolomite and locally of oolitic dolomite, altogether having a thickness of about 250 feet.[4] These strata are correlated with those containing Dikelocephalus, etc., discovered by Prof. Comstock in 1874.

The Teton Mountain district was studied by Prof. Orestes St. John in 1877, and in his report he refers to the work of Prof. Bradley in 1872. Very little is added to the information given by Prof. Bradley of the lower quartzite series, but an important advance is made in the classification of the rocks of the district by the division of Prof. Bradley's Quebec group into the Upper and Lower Quebec limestone. The Lower Quebec limestone, carrying Conocoryphe and Dikelocephalus, is described in detail and separated from the upper limestone carrying Raphistoma, etc.[5]

The line of separation of these two limestones is the line between the Cambrian and Silurian (Ordovician) Systems, and reference will be made to it under the description of the Cambrian rocks of Wyoming.

Prof. St. John also studied the Buffalo Fork Mountain, east of the Teton Range, and found there the same succession of beds as in the Teton section. Numerous fossils were collected from the limestone overlying the quartzite.[6]

[1] Geological report. Report upon the reconnaissance of northwestern Wyoming, made in the summer of 1873, by William A. Jones. 1874, pp. 107, 108.

[2] Op. cit., p. 110.

[3] Report on the geology of the Sweetwater district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, p. 71.

[4] Op. cit., p. 72.

[5] Report of the geological field-work of the Teton Division. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, pp. 481–483.

[6] Op. cit., p. 469.

In his report on the geology of the Wind River district, made in 1883, Prof. St. John describes the geology of the Gros Ventre Range, accompanying it with two plates of sections across the range at various points.[1] On the map accompanying the volume the geographic distribution of the strata referred to the Silurian is delineated. He also describes the out-crops of the strata on the northwestern and northeastern sides of the Wind River Range, that he refers to the Silurian.[2] Reference to Prof. St. John's sections will be made in describing the Cambrian rocks of the Wind River and Gros Ventre Ranges.

On the map accompanying the twelfth annual report of the Hayden survey, issued in 1883, the geographic distribution of the strata referred to the Silurian in the Sweetwater Range, the Wind River Range, the Gros Ventre Range, and the Teton Range is shown. The Silurian includes the quartzite referred to the Potsdam, the Cambrian limestone referred to the Lower Quebec by Prof. St. John, and the Calciferous referred by him to the Upper Quebec. This map was compiled from the work of Messrs. Peale, St. John, and Endlich. There is also a special map showing the district reported on by Prof. St. John in 1883.

DAKOTA.

The presence of evenly bedded sandstones about the Black Hills was noted as early as 1822 by Dr. Edwin James, who represented them upon a diagrammatic section, extending from the Alleghany to the Rocky Mountains. He undoubtedly confused the sandstones of the Trias with those of the Cambrian; but it is one of the earliest recorded illustrations of the mode of occurrence of the sandstone in this region. That he did not penetrate to the interior portion of the hills is evident, as this section represents the sandstone extending in level horizontal layers entirely across the area occupied by them.[3]

In 1856 Mr. H. Engelmann published a description of the rocks of the Black Hills. The strata next to the granitic nucleus are described as "more or less altered sandstones and limestones, dipping in various directions and degrees. Most of the sandstones are fine grained, light yellowish red, and do look much like metamorphic, but some show the transition into a siliceous rock."[4] Not far from camp 56 he found a friable sandstone made up of coarse square grains of granite, apparently deposited after the formation of the igneous rocks. Near camp 58 the sandstone is light yellowish red and fine grained. There is also a gray variety, above which is a layer of a dark red sandstone, coarse grained, soft, and highly micaceous.[5] This is the sandstone in which Dr. Hayden subsequently found the Upper Cambrian fauna.

[1] Report on the geology of the Wind River district. U. S. Geol. Surv. of the Terr., 12th Annual Report, 1883, p. 208.

[2] Op. cit., pp. 251–253.

[3] Geological sketches of the Mississippi Valley. Phil. Acad. Sci., Jour., vol. 2, pt. 2, 1822, pp. 326–329.

[4] Report of a geological exploration from Fort Leavenworth to Bryan's Pass, made in connection with the survey for a road from Fort Riley to Bridger's Pass, under Bryan. Rept. Sec. of War, Appendix H, 1856, p. 508.

[5] *Op. cit.*, p. 510.

In notes explaining the second edition of a geological map of Nebraska and Kansas in 1858 Dr. F. V. Hayden[1] states that the existence of the Potsdam sandstone on the eastern slope of the Rocky Mountains was discovered during Lieut. G. K. Warren's expedition to the Black Hills in the summer of 1857.

In March, 1858, Messrs. Meek and Hayden presented a paper to the Academy of Natural Sciences, Philadelphia, containing "some remarks on the geology of the Black Hills and portions of the surrounding country." In this a section of the formations is given, in which the "Potsdam" sandstone is given a thickness of 30 to 50 feet and is said to contain Lingula, Obolus ?, and fragments of trilobites.[2] The sandstone is described as of a reddish and grayish color, composed of angular grains of quartz, cemented by siliceous and sometimes small portions of calcareous matter. The fossils then identified were *Lingula antiqua* Hall, great numbers of a small shell similar to *L. prima* Conrad and fragments of trilobites.[3] The information contained in this first paper by Messrs. Meek and Hayden was also published in the American Journal of Science,[4] the Canadian Naturalist (vol. 3, 1858, pp. 182–193), the report of the Chief of Engineers to the Secretary of War, 1858,[5] the American Journal of Science (vol. 25, 2d ser., p. 439, 1858), the Proceedings of Philadelphia Academy of Science (vol. 10, p. 139, 1859), and in a reprint of the Preliminary Report of the Exploration of Nebraska and Dakota, issued in 1875, which is the official account of Lieut. G. K. Warren's exploration transmitted to the Chief of Engineers.

In a paper on the Primordial sandstone of the Rocky Mountains and Northwestern Territories of the United States Dr. Hayden describes the sandstone he referred to the Potsdam in the Black Hills in considerable detail, as follows:[6]

> 3. Variegated sandstone, of gray and ferruginous red color, composed chiefly of grains of quartz and particles of mica, cemented with calcareous matter. Some portions of the bed are very hard, compact, siliceous; others a coarse friable grit, others a conglomerate. Fossils: *Lingula prima*, *L. antiqua*, *Obolella nana*, and fragments of a trilobite, *Arionellus? oweni*. . . 50 to 80 f.
> 4. Stratified azoic rocks standing in a vertical position for the most part.

The "Potsdam" sandstone is again described by Dr. Hayden in 1863,[7] and in the following year he published, in connection with Mr.

[1] Explorations under the War Department; explanations of a second edition of a geological map of Nebraska and Kansas, based upon information obtained in an expedition to the Black Hills under command of Lieut. G. K. Warren. Am. Jour. Sci., 2d ser., vol. 26, 1858, pp. 276–278.

[2] [Some remarks on the geology of the Black Hills and portions of the surrounding country.] Phil. Acad. Sci., Proc., vol. 10, 1859, p. 44.

[3] Op. cit., p. 49.

[4] Explorations under the War Department; explanations of a second edition of a geological map of Nebraska and Kansas, based upon information obtained in an expedition to the Black Hills under command of Lieut. G. K. Warren, Top. Engr., U. S. A. Am. Jour. Sci., 2d ser., vol. 26, 1858, p. 276.

[5] Catalogue of the collections in geology and natural history obtained by the expedition under command of Lieut. G. K. Warren. Appendix to Rept. Soc. of War in Rept. of Topog. Eng. for 1858. (Reprint edition of 1875, pp. 59–125. Map.)

[6] The Primordial sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, p. 70.

[7] On the geology and natural history of the Upper Missouri. Am. Phil. Soc. Trans., vol. 12, new ser., 1863, pp. 36–38.

Meek, the description of the fossils he found in the Black Hills during the expedition of 1858. They are *Lingulepis pinnaformis*, *L. prima*, *Obolella nana*, and *Agraulos* sp.[1]

A general description of the sandstone of the Black Hills is given by Prof. N. H. Winchell in his report to Capt. William Ludlow, and the geographic distribution of the outcrop in the southern portion of the Black Hills is shown on the accompanying map.[2] In the same report Prof. R. P. Whitfield[3] describes *Obolus pectenoides*, a new species of brachiopod, and also figures *Lingulepis pinnaformis*.

The report of Mr. Henry Newton on the geology of the Black Hills contains a detailed description and full discussion of the strata referred to the Potsdam sandstone. This will be again referred to in the summary of our knowledge of the Cambrian rocks of the Black Hills.[4] From the paleontologic portion of the report we learn that the entire fauna of the Black Hills below the Carboniferous is Primordial, and Prof. R. P. Whitfield states it closely resembles that from Wisconsin, and although the species are nearly all distinct the generic facies is the same throughout.[5]

In 1888 Prof. F. R. Carpenter published a series of notes on the geology of the Black Hills, in which he criticised some of Newton's views, and also advanced some theoretical considerations of interest in relation to the original deposition of the sediments forming the Potsdam group.[6]

SOUTHWESTERN SUBPROVINCE.

This includes the areas of Texas and Arizona.

TEXAS.

The presence of Silurian rocks in Texas, subsequently referred to the Primordial, was announced by Dr. F. Roemer in 1849.[7] In the same work he describes from the lower portion of the section *Lingula acutangula* (p. 420) and *Pterocephalia sancti-sabæ* (p. 421).

On the map accompanying this volume the entire Paleozoic series is included under one color, on the northern side of the granitic band, northwest of Austin.

---

[1] Paleontology of the Upper Missouri; a report upon collections made principally by the expedition under command of Lieut. G. K. Warren in 1855-'56. Invertebrates. Smithsonian Contributions No. 172, 1864, pp. 2-10.

[2] Geological report of a reconnaissance of the Black Hills of Dakota, made in the summer of 1874 by Captain William Ludlow. Report of the Chief of Engineers, Appendix PP, 1876, p. 1170.

[3] Description of new fossils. Report of Geological Reconnaissance of Black Hills. Appendix PP of Report of Chief of Engineers, 1876, pp. 1202, 1203.

[4] Geology. Section IV. The Silurian. The Potsdam sandstone. U. S. Geog. and Geol. Surv. of the Rocky Mountain region, J. W. Powell in charge; report on the Black Hills of Dakota. 1880, pp. 80-107.

[5] Paleontology of the Black Hills of Dakota. Report on the geology and resources of the Black Hills of Dakota. 1880, pp. 329, 330.

[6] Notes on the geology of the Black Hills. Preliminary Rept. Dakota School Mines on the Black Hills of Dakota, 1888, pp. 11-52.

[7] Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physichen Verhältnisse des Landes nach eigener Beobachtung geschildert. Bonn, 1849.

A more extended account of the geology and the paleontology was published by him in 1852, in which he notes the occurrence of Silurian rocks in Llano County, on the San Saba River (p. 7); and describes and illustrates *Lingula acutangula* (p. 90), *Pterocephalia sancti sabæ* (p. 92), and the genus Pterocephalia. Attention is called by notes and figures to two undescribed species of trilobites.[1]

In a letter addressed to the Secretary of the St. Louis Academy of Sciences in 1859 Dr. B. F. Shumard states that he had discovered in Burnet County, Texas, an extensive development of Lower Silurian rocks, equivalent to the Potsdam sandstone and the Calciferous sandrock of the New York system. The Potsdam sandstone is filled with trilobites belonging to the old genus Arionellus, with Obolus and Lingula, and a small Orthis, and it rests directly upon the granite. Above the Potsdam we have beds which appear to represent the third magnesian limestone and second magnesian limestone of the Missouri survey.[2] Two years later Dr. Shumard published a more detailed account of the Primordial zone of Texas, accompanied by a number of sections measured in Burnet County, and a description of new species of fossils from limestones referred to the Primordial. Under the heading of "Potsdam sandstone" three sections are given; one, 5 miles northwest of the town of Burnet, has a thickness of 275 feet. In this fossils were abundant in the upper portion, just beneath the Cretaceous limestone, as well as in the lower beds. The base was not seen. This section is made up almost entirely of limestones, as are the other two sections mentioned.[3]

Dr. Shumard states that the Potsdam sandstone is also finely displayed in the southern part of San Saba County and around the margins of the granite districts of Llano. "The fauna of this division of the Primordial zone of Texas is very analogous to that of the Potsdam sandstone of Iowa, Wisconsin, and Minnesota." The genera identified are: "Dikelocephalus, Bathyurus, Arionellus, Conocephalites, Agnostus, Lingula, Discina, Orthis, Camerella, Obolus, and Capulus, all of which genera have been discovered in the Primordial sandstones of the northwest except Agnostus and Camerella."[4] In the latter part of the paper six new species were described, and a species of Camarella and one of Capulus mentioned. In a letter to M. Barrande, dated September, 1860, Dr. Shumard describes in a general way the Primordial rocks of Texas as seen along the Colorado River in Burnet County.[5]

Attention was called in 1874 to the presence of a sandstone in Organ Mountains, close to the city of El Paso, in southwestern Texas, by Mr.

[1] Die Kreidebildungen von Texas und ihre organischen Einschlüsse. Bonn, 1852, pp. 92, 93.

[2] Letter touching the late discovery of Lower Silurian rocks, equivalent to the Potsdam sandstone and Calciferous sandrock of the New York system, in Burnet County, Texas. Trans. Acad. Sci. St. Louis, vol. 1, 1859, pp. 672, 673.

[3] The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci., 2d ser., vol. 32, 1861, pp. 216, 217.

[4] Op. cit., pp. 217, 218.

[5] Letter on the Primordial of Texas. Soc. géol. France, Bull., 2e sér., vol. 18, 1861, pp. 218, 219.

W. P. Jenney. He states that the quartzite rests upon a coarse feldspathic granite, and passes upward into sandstone, filled with *Scolithus linearis*, which he identified as the Potsdam sandstone. The superjacent formation is a crystalline limestone identified as calciferous. It contains several species of fossils resembling Archæocyathus, and rarely a gasteropod, like Pleurotomaria.[1] In commenting upon the statements of Mr. Jenney, Prof. J. S. Newberry says:

> Now it appears there are found in the Rio Grande Valley the crystalline base-rocks overlaid in succession by the Potsdam and Primordial, the Trenton, Hudson, Upper Silurian (?), and Carboniferous, just as they occur in the Northern and Eastern States. * * * It would seem as though the Organ Mountains had formed one border, and the New York and Canadian highlands the other, of the great Paleozoic invasions of the sea.[2]

A section of the strata referred in 1874 to the Potsdam by Mr. S. B. Buckley, at Packsaddle Mountain, in Llano County, gave a thickness of 385 feet of alternating limestone and sandstone, beneath which occurs a massive bed of reddish brown sandstone 326 feet in thickness. Numerous genera of Primordial fossils were found, characteristic of this horizon.[3] Other references are made to the occurrence of the Potsdam sandstone at various localities in this county. In the report for the following year Mr. Buckley refers to the occurrence of sandstones of the Potsdam period in Mason and Menard Counties. He also calls attention to the probable presence of rocks of Silurian age at the base of the Organ Mountains at Fort Bliss, near the town of El Paso.[4]

A preliminary report of a reconnaissance of a portion of the Paleozoic area of central Texas was made by Mr. C. D. Walcott in 1884. A measured section of the strata referred to the Cambrian on the west side of Honey Creek Valley gives 245 feet of sandstone and 625 feet of limestone, all marked by the presence of an abundant Upper Cambrian (Potsdam) fauna. The upper beds of the limestone become compact, hard, and have a little included cherty matter. The Cambrian fauna terminates here, as far as observed, and it is not until over 1,000 feet of limestone are passed through that recognized fossils again occur. The fauna is then of the type of the Calciferous group.[5] The text is accompanied by a diagrammatic section of Packsaddle Mountain, that illustrates the unconformity between the Llano group and the strata referred to the Potsdam or Upper Cambrian. This gave a total thickness of 605 feet for the formation, with a massive sandstone 205 feet in thickness at the base.[6]

The latest addition to our knowledge of the Cambrian rocks of Texas

---

[1] [Recent explorations in the Geology of Texas.] New York Lyceum Nat. Hist. Proc., vol. 2, 1874, p. 69.

[2] Remarks on geology of Western Texas. New York Lyceum Nat. Hist.. Proc. vol. 2, 1874, p. 70.

[3] First annual report of the geological and agricultural survey of Texas. Houston, 1874, p. 73.

[4] Second annual report of the geological and agricultural survey of Texas. Houston, 1876, p. 10.

[5] Notes on Paleozoic rocks of Central Texas. Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 433.

[6] *Op. cit.*, p. 432.

is by Prof. T. B. Comstock.[1] He divides the rocks referred to the Cambrian into the Hickory series (Lower Cambrian?), the Riley series (Middle Cambrian?), and the Katemcy (Potsdam) series (Upper Cambrian?). The supposition that the Lower Cambrian and Middle Cambrian are represented is based upon the presence of certain beds beneath the fossiliferous Upper Cambrian. He considers that the Hickory beds have altogether a thickness of 200 to 250 feet. The maximum thickness of the Riley series is probably 300 to 400 feet. The upper or Katemcy series is divided into, Division A, or the Potsdam sandstone, thickness 90 to 140 feet; Division B, the Potsdam flags, probable thickness 50 feet; Division C, the Potsdam limestone, 200 feet.

ARIZONA.

As geologist of Lieut. J. C. Ives's expedition to the Colorado River of the West, Prof. J. S. Newberry was the first one to recognize the presence of a sandstone resting upon the Archean granite in the "Big Cañon" of the Colorado. A diagrammatic cross-section of the cañon represents the "Potsdam" sandstone unconformably superjacent to the granite and conformably subjacent to strata doubtfully identified as Silurian.[2] In the text it is said "the Potsdam (?) sandstone which is largely developed in the Great Cañon is a coarse siliceous rock that must have been derived from the erosion of land at no great distance."[3]

A section at Diamond Creek, as described by the same author, includes a conglomerate 3 feet in thickness resting on the granite, above which occurs 820 feet of sandstone. Of the upper beds of the sandstone, No. 10 of the section, Prof. Newberry says:

> The foliated sandstones of No. 10 have an indescribable look of antiquity. They are usually fine grained and hard, the lighter ones drab or gray, speckled with dark red. The shales above and below these sandstones are very soft red or green mudstones, containing great numbers of cylindrical bodies, which resemble the casts of worm holes.
>
> Nos. 12 and 13 are coarse siliceous rocks, having the same appearance of extreme age as No. 10, but much coarser and more massive. The lithological characters of these strata are strikingly like those of much of the Potsdam sandstone of the exposures I have examined of that rock on Lake Superior and in Canada. * * * In the absence of fossils, whatever conclusions may be arrived at in regard to the age of these sandstones must be in some degree conjectural and liable to modification by the discovery of new facts; yet the evidence is in a good degree satisfactory that they are the equivalent of the Potsdam sandstone of the New York geologists. The indications of this identity are found in their great relative antiquity and in their lithological characters.[4]

Attention is called to the resemblance of these sandstones to those of the Black Hills which occupy the same relative stratigraphic posi-

[1] A preliminary report on the geology of the central mineral region of Texas. 1st Ann. Rep. Geol. Surv. of Texas for 1889, 1890, pp. 285-289.

[2] Geological report. Report upon the Colorado River of the West, expl. in 1857-'58 by Lieut. J. C. Ives. Part III, 1861, p. 42.

[3] Op. cit., p. 47.

[4] Op. cit., p. 56

tion, and which contain the Potsdam fauna, as identified by Dr. Hayden.[1]

When describing the section of the Grand Cañon of the Colorado where it passes through the Kaibab plateau, Maj. J. W. Powell states that the summit of the section was formed by Carboniferous limestone. This extends from the edge of the plateau down 3,500 feet, and beneath it occurs 1,000 feet of conformable rocks of undetermined age. These in turn extend down to the unconformity between them and the subjacent 10,000 feet of strata that were subsequently referred to the Grand Cañon group. At the close of the same paragraph, in speaking of the latter series of rocks, he says:

> The beds themselves are not conformable to the overlying Carboniferous rocks; that is, the Carboniferous rocks are spread over their upturned edges.[2]

It thus appears that all of the strata down to the unconformity were referred to the Carboniferous. This includes the series of sandstones referred to the Potsdam by Dr. Newberry.

As the result of his studies of the lower strata of the Colorado Cañon region at Diamond Creek and at the mouth of the cañon, Mr. G. K. Gilbert in 1874 designated the series of sandstones referred to the Potsdam by Newberry, as the Tonto group, and considered it to belong to the Primordial division of the Silurian.[3] The data for this conclusion were published in the following year.[4]

The section at the mouth of the Colorado has 80 feet of vitreous sandstone resting unconformably upon the granite, and 605 feet of shales alternating with limestones between the sandstone and a superjacent massive limestone.[5] At the mouth of the Kanab Creek 100 feet of green arenaceous and micaceous shales occur between the superjacent massive gray limestone and the level of the river.[6] From the stratigraphic position of the Tonto sandstone and shales and the presence of a species of the genus Cruziana he was led to conclude that the Tonto group is certainly Lower Silurian in age, and probably Primordial.[7]

The section of the Tonto series at the mouth of the Grand Cañon was measured more in detail by Mr. A. R. Marvine in the same year. He traced[8] the formation to the south and southeast along the margin of

---

[1] Op. cit., p. 57.

[2] Exploration of the Colorado River of the West and its tributaries, explored in 1869, 1870, 1871, and 1872. Washington, 1875, p. 212.

[3] On the age of the Tonto sandstone. (Abstract.) Washington Phil. Soc. Bull., vol. 1, 1874, p. 103.

[4] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, pp. 184 186. Report on the geology of portions of New Mexico and Arizona, examined in 1873. Ibid., vol. 3, 1875, pp. 521, 522.

[5] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 163.

[6] Op. cit., p. 162.

[7] Op. cit., pp. 185, 186.

[8] Report on the geology of route from St. George, Utah, to Gila River, Arizona, examined in 1871. *Rept. on Geog. and Geol. Expl. and Surv. west of 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology*, 1875, p. 199.

the plateau that extends southward from the Grand Cañon. The geographic distribution of the formation is indicated on the atlas sheets published by the Wheeler survey in 1874.

When describing the sedimentary groups of the Plateau province Maj. Powell accepted the name Tonto group, proposed by Mr. Gilbert, but did not agree with him in considering the strata to be of Silurian age. From geological considerations he was inclined to consider the Tonto group as forming the base of the Carboniferous series. This opinion was strengthened by the fact that he found in the Grand Cañon 10,000 feet of sandstone, shales, and limestones underlying the Tonto series unconformably, and hence separated from them by long periods of erosion, and at the base of the latter series he reported finding Silurian fossils.[1]

The fossils mentioned by Maj. Powell were studied by Dr. C. A. White, who identified the genera Lingulella and Obolella and referred them to the Lower Silurian.[2]

The supposed Primordial age of the Tonto series was accepted by Capt. C. A. Dutton in his account of the physical geology of the Grand Cañon district.[3]

The section at the mouth of the Kanab Cañon was studied by Mr. C. D. Walcott in 1880. He found that 450 feet of a mottled limestone and 100 feet of arenaceous and micaceous shales at the base of the section were of Primordial age, as indicated by the presence of the genera Lingulepis, Conocephalites, and Bathyurus in the upper portion, and in addition to these *Hyolithes primordialis*, Lingulepis, and Crepicephalus in the lower beds.[4] Further evidence of the Cambrian age of the Tonto group was published by Mr. Walcott in 1883. Fossils representing the genera Cruziana, Lingulepis, Iphidea, Conocephalites, Crepicephalus, and Dikelocephalus were found in the upper 700 feet of the sandstones, shales, and limestones that form the upper part of the group in the cañon valleys entering on the left side of the Kaibab plateau.[5]

PALEONTOLOGY.

UPPER MISSISSIPPI AREA.

The first reference that we find to the fossils of the Cambrian fauna of the Upper Mississippi Valley is by Dr. D. D. Owen in his report of 1848 on a geological reconnaissance of the Chippewa land district of

[1] Report on the geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto. Washington, 1876, p. 56.

[2] Invertebrate paleontology of the Plateau province, together with notice of a few species from localities beyond its limits in Colorado. Rept. on the geology of the eastern portion of the Uinta Mountains, by J. W. Powell, Washington, 1876, p. 70.

[3] The physical geology of the Grand Cañon district. U. S. Geol. Surv., 2d Ann. Rep. 1880–'81. 1882, p. 114.

[4] The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, 1880, p. 225.

[5] Precarboniferous strata in the Grand Cañon of the Colorado, Arizona. Am. Jour. Sci., 3d ser., vol. 26, 1883, p. 439.

Wisconsin.[1] The fossils discovered were referred to the genera Asaphus, Agnostus, Trinucleus, and Triarthrus, but on Pl. 7, accompanying the report, there is figured, but not named, the head and pygidium of *Dikelocephalus minnesotensis*, and a species of Ptychoparia as now known.

In a later paper in 1851 on the paleontology of the lowest sandstones of the Northwest he gives the name "Dikello-Cephalon" to a large genus of trilobites obtained in the lower sandstone formation.[2] He also notes the discovery of Lingulas and Orbiculas by himself in 1847 at the Falls of St. Croix, and the discovery of fossils on the Mississippi River between the Falls of St. Anthony and the Wisconsin River, the presence of trilobites in the sandstone 10 miles below Mountain Island, etc.

One of the first species described from the "Potsdam" sandstone of Wisconsin is *Graptolithus hallianus* Prout, 1851, from the middle portion of the formation at Osceola Mills, near the falls of St. Croix River.[3]

The occurrence of the Potsdam fauna in the sandstone of northeastern Wisconsin is noted by Prof. James Hall in his report to Messrs. Foster and Whitney.[4] He describes and illustrates *Lingula prima* Conrad (p. 204), *Lingula antiqua* Hall (p. 204), and an undetermined species of Dikelocephalus (p. 205).

We note that *Lingula prima* was subsequently described by Hall as *Obolella polita*, and that *Lingula antiqua* equals *Lingulepis acuminata* of Conrad and the *Lingulepis pinnaformis* of Owen.

From the material collected from the lower sandstones of Wisconsin (the Potsdam sandstone of New York) Dr. Owen described, in 1852, the following genera and species:[5]

Dikelocephalus (n. gen.), p. 573.
- minnesotensis, p. 574.
- pepinensis, p. 574.
- miniscaensis, p. 574.
- iowensis, p. 575.
- granulosus, p. 575.

Lonchocephalus (n. gen.), p. 575.
- chippewaensis, p. 576.
- hamulus, p. 576.

Crepicephalus (n. gen.), p. 576.

Menocephalus (n. gen.), p. 577.

In the description of Pl. 1 the species *Menocephalus minnesotensis* is named and figured (Fig. 11); also *Crepicephalus ? wisconsensis* (Fig. 13), and on Pl. 1*a*, *Crepicephalus* (?) *miniscaensis* is named and illustrated (Fig. 14). On Pl. 1*b*, the species *Lingula pinnaformis* is proposed and illustrated (Figs. 4, 6, 8); *Lingula ampla* is figured and named

[1] Report of a geological reconnaissance of the Chippewa land district of Wisconsin; and incidentally, of a part of Iowa and of the Minnesota Territory. Letter of the Secretary of the Treasury communicating a report of a geological reconnaissance of the Chippewa land district of Wisconsin (etc), by D. D. Owen. Thirtieth Congress, 1st Sess., Senate Ex. Doc. No. 57, 1848, pp. 13 15.

[2] Am. Assoc. Proc., vol. 5, 1851, p. 171.

[3] Description of a new Graptolite found in the Lower Silurian rocks near the falls of the St. Croix River. Am. Jour. Sci., 2d ser., vol. 11, 1851, p. 189.

[4] Description of new or rare species of fossils from the Paleozoic series. Rept. on the geology of the Lake Superior land district, by Foster and Whitney, pt. 2, 1851, pp. 203–231.

[5] Geol. Surv. of Wisc., Iowa, and Minn., and, incidentally, of a portion of Nebraska Territory. Philadelphia, 1852.

(Figs. 5, 12), together with figures of *Lingula antiqua* and *L. prima*, and a number of others placed under Obolus and Orbicula.

Mr. Edward Daniels stated in 1859 that upon a small island in Black River he had found perfect impressions of crustaceans consisting of double rows of parallel tracks, precisely like those in Montreal.[1] (Protichnites of Logan.—C. D. W.)

In the report of the superintendent of the geological survey of Wisconsin, Prof. Hall describes, from the Potsdam sandstone:[2]

Lingula polita, p. 24.
Lingula aurora, p. 24.
Theca primordialis, p. 48.
Serpulites murchisonia, p. 48.

In the geological volume he illustrates:[3]

Graptolithus (Dendrograptus) hallianus, p. 21.
Lingula polita, p. 21.
pinnaformis, p. 21.
antiqua, p. 21.
aurora, p. 21.
Theca primordialis, p. 21.
Serpulites murchisonii, p. 21.
Dikelocephalus minnesotensis, p. 22.
D. pepinensis, p. 22.

In a letter to Principal J. W. Dawson, Prof. Hall describes a new crustacean from the Potsdam sandstone under the generic name of Aglaspis, stating it to be the same form mentioned in a communication to the Albany Institute.[4]

In 1862 Prof. C. H. Hitchcock published a list of the fossils of the Potsdam group in North America, including in it all the species known to him described from the Potsdam sandstone and also from the strata now referred to the Cambrian of other parts of North America. The list includes one hundred and thirty-four species.[5]

In 1862 Prof. B. F. Shumard describes from the Potsdam sandstone of Wisconsin and Missouri the following species:[6]

Dikelocephalus latifrons, p. 101.
Arionellus bipunctatus, p. 101.
Conocephalites minor, p. 105.

He also noticed under the name of *Conocephalites iowensis*, the *Dikelocephalus* (?) *iowensis* of Owen (p. 102), and *Crepicephalus* (?) *wisconsensis*, under the name of *Conocephalites wisconsensis* (p. 103). The *Lonchocephalus chippewaensis* Owen and *L. hamulus* are both referred to the genus Conocephalites (p. 104). A species of Agnostus was referred to *Agnostus orion* (?) of Billings (p. 105).

[1] Notes on geology of Wisconsin and adjacent States. Boston Soc. Nat. Hist. Proc., vol. 6, 1859, p. 310.

[2] Report of the superintendent of the geological survey (of Wisconsin), exhibiting the progress of the work. January 1, 1861. Madison, 1861, pp. 52.

[3] Physical geography and general geology. Geol. Surv. Wisconsin, Report, vol. 1, 1862, pp. 1-72.

[4] On a new crustacean from the Potsdam sandstone. Canadian Naturalist, vol. 7, 1862, p. 445.

[5] Fossils of the Potsdam group in North America. Portland Soc. Nat. Hist. Proc., vol. 1, 1862, pp. 87-90.

[6] Notice of some new and imperfectly known fossils from the Primordial zone (Potsdam sandstone and Calciferous Sand-group of Wisconsin and Missouri. St. Louis Acad. Sci. Trans., vol. 2, 1862, pp. 101-105.

In the same year Prof. James Hall read before the Albany Institute a preliminary notice of the fauna of the Potsdam sandstone, with remarks upon the previously known species and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. This was first published in the Sixteenth Report of the State Cabinet of Natural History in 1863, and in 1867 in the Transactions of the Albany Institute. The new genera and species described are as follows:[1]

Lingula winona, p. 126.
mosia, p. 126.
aurora var., p. 127.
Discina (?) inutilis, p. 130.
Orthis pepina, p. 134.
Platyceras primordialis, p. 136.
Euomphalus (?) vaticinus, p. 136.
Dikelocephalus minnesotensis var. limbatus, p. 141.
Dikelocephalus minnesotensis var., p. 141.
Dikelocephalus spininger, p. 143.
misa, p. 144.
osceola, p. 146.
Conocephalites eos, p. 151.
perseus, p. 153.
shumardi, p. 154.
nasutus, p. 155.
oweni, p. 155.
eryon, p. 157.
anatinus, p. 158.
patersoni, p. 159.
? binodosus, p. 160.
winona, p. 161.
diadematus, p. 167.
Ptychaspis sp.?, p. 174.
Chariocephalus whitfieldi, p. 175.
Illaenurus quadratus, p. 176.
Triarthrella auroralis, p. 177.
Agnostus josepha, p. 178.
parilis, p. 179.
disparilis, p. 179.
Aglaspis barrandi, p. 181.
Pemphigaspis bullata, p. 221.
Amphion ? matutina, p. 222.
Conocephalites ? (Arionellus ?) dorsalis, p. 222.
Conocephalites optatus, p. 222.

Of species previously described he redescribed and illustrated:

Graptolithus hallianus, Prout., as Dendrograptus hallianus, p. 124.
Lingula ampla, Owen, p. 125.
aurora, Hall, p. 126.
pinnaformis, Owen, as Lingulepis pinnaformis, p. 129.
Obolus apollinus Owen, as Obolella ? polita, p. 133.
Lingula ? polita Hall, as Obolella ? polita, p. 133.
Theca primordialis Hall, p. 135.*
Serpulites murchisoni, Hall, p. 136.*[2]
Dikelocephalus minnesotensis, Owen, p. 138.
pepinensis, Owen, p. 142.
Conocephalites minor, Shumard, p. 149.
minutus, Bradley, p. 150.
Dikelocephalus iowensis, Owen, as Conocephalites iowensis, p. 162.
Crepicephalus ? wisconsensis, Owen, as Conocephalites winconsensis, p. 164.
Conchocephalus hamulus, Owen, as Conocephalites hamulus, p. 166.
Arionellus bipunctatus, Shumard, p. 169.
Dikelocephalus miniscaensis, Owen, as Ptychaspis miniscaensis, p. 171.
granulosus, Owen, as Ptychaspis granulosa, p. 173.

Agnostus orion (?) Billings, noted by Shumard, is described as *Agnostus josepha* (p. 178). The genus Dikelocephalus is redefined (p. 137),

[1] Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Regents Univ. State Cab. Nat. Hist., 1863, pp. 119-230. Albany Inst. Trans., vol. 5. 1867, pp. 93-195.

[2] Pages 135, 136 each have an asterisk (*) placed after them to indicate interpolated pages.

and the genus Obolella of Billings is described with special reference to the species *Obolella polita* (pp. 131–134).

The new genera described are:

Lingulepis, p. 129.
Ptychaspis, p. 170.
Chariocephalus, p. 175.
Illænurus, p. 176.
Triarthrella (subgenus), p. 177.
Aglaspis, p. 181.
Pemphigaspis, p. 221.

The genus Conaspis is proposed in the event of a new generic group being formed of *Conocephalites perseus*, *C. shumardi*, *C. nasutus*, *C. oweni*, *C. eryon*, *C. anatinus*, and *C. patersoni* (p. 152).

Prof. Hall states that he was unable to recognize the six successive trilobite beds of the sandstone as indicated by Dr. Owen, but he nevertheless refers the species described to three different epochs of the Potsdam period, as follows:

In the lower beds of the formation I have found Conocephalites proper, together with Lingula, Lingulepis, Obolella? and Theca. In the middle stage, neither the limits of the beds, nor the range of species or genera, have been so well determined; but, grouping together all that I have found between the well-defined upper beds and the lower fossilferous beds known, we have Conocephalites, Dikelocephalus, Arionellus, Ptychaspis, Chariocephalus, Illænurus and Agnostus, in the trilobitic fauna, together with Orthis and Platyceras.

The Graptolitidæ apparently begin their existence somewhere in this central epoch, but their precise relations to the other beds have not been determined.

In the higher beds of the formation, and clearly separated from the great central mass, we have the genera Dikelocephalus, Triarthrella, and Aglaspis, together with Lingula, Serpulites, and Euomphalus.

We observe, therefore, that the earliest trilobites are referable to the genus Conocephalites; and the genus Dikelocephalus does not appear in the first stages of the formation, nor below the beds which I have referred to the second or middle stage of the period. There this genus appears in three species, smaller and less conspicuous than those in the higher beds. It is only in the later stages of the sandstone that the typical species of this genus of Dr. Owen appear, and those from the lower beds, thus referred by him, belong apparently to other genera.[1]

From a small collection of fossils from the Potsdam sandstone of Sauk County, Wisconsin, Dr. Alexander Winchell describes in 1864 four new species and mentions the presence of some others that have been described.[2] The new species are:

Orthis barabuensis, p. 228.
Straparollus (Ophileta) primordialis, p. 228.
Pleurotomaria? advena, p. 228.
Ptychaspis barabuensis, p. 230.

He mentions the occurrence of *Scolithus linearis* (p. 227) and *Dikelocephalus minnesotensis* and *Dikelocephalus pepinensis* (p. 229). From the Lake Superior sandstone he describes *Palæophycus articulatus* (p. 231) and *P. informis* (p. 232). The two latter species are doubtfully re-

[1] Op. cit., p. 183.

[2] Notice of a small collection of fossils from the Potsdam Sandstone of Wisconsin and Lake Superior Sandstone of Michigan. Am. Jour. Sci., 2d ser., vol. 37, 1864, pp. 226-232.

ferred to the Cambrian fauna. In this paper, Dr. Winchell points out, or, rather, he claims, that Dikelocephalus and Ptychaspis occur at the recognized base of the Potsdam sandstone.[1]

The preliminary notice of the fauna of the Potsdam sandstone of the upper Mississippi Valley read before the Albany Institute in 1862, by Prof. J. Hall, was published with illustrations in 1863, as has been noticed. The original paper appeared in 1867 in the transactions of the Albany Institute. The descriptions are the same as those of the paper of 1863, with the exception of the omission of those of *Theca primordialis* and *Serpulites murchisoni*.

From the material collected by the Wisconsin Geological Survey Prof. R. P. Whitfield described in 1878 under the title of Potsdam sandstone species:[2]

Palæophycus plumosus, p. 50.
Triplesia primordialis, p. 51.
Palæacmæa irvingi, p. 51.
Bellerophon antiquatus, p. 52.
Conocephalites calymenoides, p. 52.
Crepicephalus onustus, p. 53.
Ptychaspis striatus, p. 55.
minuta, p. 55.
Agraulos (Bathyurus?) woosteri, p. 56.
Arionellus (Agraulos) convexus, p. 57.
Ellipsocephalus curta, p. 58.

Dikelocephalus granulosus, Owen, is redefined under *Ptychaspis granulosa*, but not the *Ptychaspis granulosa* of Hall (p. 54). *Ptychaspis granulosa*, Hall, is redescribed as *P. striata* (p. 55).

In 1879 Prof. T. C. Chamberlin referred to some tracks found on the Potsdam sandstone by Rev. A. A. Young, of New Lisbon, Wisconsin. He named *Climactichnites youngi* and *C. fosteri*. The material was subsequently studied by Mr. J. E. Todd, who published an illustration and description of the species. These tracks or trails are congeneric with *Climactichnites wilsoni*, described by Logan in 1863, from Perth, Canada.[3]

In 1882 in his final report on the paleontology of Wisconsin, Prof. R. P. Whitfield described from the Potsdam sandstone the following new species:[4]

Holopea sweeti, p. 174.
Conocephalites? quadratus, p. 180.
(Ptychaspis?) explanatus, p. 181.
Dikelocephalus lodensis, p. 188.
Aglaspis eatoni, p. 192.
Arenicolites woodi, p. 177.

He also describes and illustrates:

Paleophycus plumosus Whitf., p. 169.
Lingulepis pinnaformis, Owen, p. 169.
Orthis pepina, Hall, p. 170.
barabuensis, Winchell, as Leptæna barabuensis, p. 171.
Triplesia primordialis Whitt., p. 172.

[1] Op. cit., p. 226.

[2] Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin. Geol. Surv. of Wisconsin, Ann. Rep. for 1877, 1878, pp. 50–58.

[3] A description of some fossil tracks from the Potsdam sandstone. Wisconsin Acad. Sci., Trans., vol. 5, 1882, pp. 276–281.

[4] Paleontology (of Wisconsin). Geology of Wisconsin, vol. 4, 1882, pp. 169–193.

Palæacmæa irvingi, p. 173.
Straparollus (Ophileta) primordialis, Winchell, as Ophileta (Raphistoma) primordialis, p. 173.
Theca primordialis, Hall, as Hyolithes primordialis, p. 175.
Bellerophon antiquatus, Whitf., p. 176.
Conocephalites calymenoides, Whitf., p. 179.
Crepicephalus onustus, Whitf., p. 182.
Conocephalites gibbsi, Whitf., as Crepicephalus? gibbsi, p. 184.
Dikelocephalus granulosus, Owen, as Ptychaspis granulosa, p. 185.
Ptychaspis granulosa, Hall, as P. striata, p. 186.
minuta, Whitf., p. 186.
Dikelocephalus minnesotensis Owen, p. 187.
Agraulos (Bathyurus?) woosteri, Whitf., p. 189.
Arionellus (Agraulos) convexus, Whitf., as Arionellus convexus, Whitf., p. 190.
Ellipsocephalus curtus, Whitf., p. 191.

In the preliminary remarks on the fauna he says:

It is a matter of considerable interest that, in different localities of the Potsdam formation, the forms of trilobites found are generally specifically distinct; and notwithstanding the large number of species already described from this formation, both in this State and other parts of the country, other new forms, readily detected by those familiar with the several details of structure peculiar to these animals, are met with at almost every new locality examined. This change in species between different localities is usually accompanied also by some slight difference in the material or composition of the rock, which not only shows that the species were of short duration in time, or that they were restricted to limited geographical areas, but that a change in the conditions of life and circumstances under which the animals existed, and with which they had to contend, was constantly taking place. How much these circumstances or conditions had to do with the production of forms, or modification of types among them, it would be difficult to determine; but one thing is certain, that where the same character of rock and apparent conditions of deposition prevail over a limited geographical area, or are repeated within a slight vertical range, we are pretty sure to find the same, or closely allied forms represented, showing that under like conditions similar forms prevail.[1]

In 1883, when describing the life of the Potsdam epoch, in the General Geology of Wisconsin, Prof. T. C. Chamberlin illustrates the following species:[2]

Palæophycus plumosus, p. 125, Fig. 11.
Bellerophon antiquatus, Whitfield, p. 126, Fig. 12, a, b.
Ophileta primordialis, Winchell, p. 126, Fig. 12, c, d.
Holopea sweeti, Whitfield, p. 126, Fig. 12, e.
Palæacmæa irvingi, Whitfield, p. 126, Fig. 12, f.
Platyceras primordialis, Hall, p. 126, Fig. 12, g.
Serpulites murchisoni, Hall, p. 126, Fig. 12, h.
Theca primordialis, Hall, p. 126, Fig. 12, i.
Dendrograptus hallianus, Prout, p. 126, Fig. 12, j.
Lingula antiqua, Conrad, p. 127, Fig. 13, b.
Lingulella stoneana, Whitfield, p. 127, Fig. 13, a.
aurora, Hall, p. 127, Fig. 13, c.
ampla, Hall, p. 127, Fig. 13, d.
mosia, Hall, p. 127, Fig. 13, e.

[1] Op. cit., pp. 163. 164.
[2] General Geology. Historical Geology. Paleozoic Era. Geol. Wis. Survey of 1873–1879, vol. 1, 1883.

Lingulepis pinnaformis, Owen, p. 127, Fig. 13, f, g.
Obolella polita, Hall, p. 127, Fig. 13, h.
Orthis pepina, Hall, p. 127, Fig. 13, i, j, k, l.
Triplesia primordialis, Whitfield, p. 127, Fig. 13, m.
Leptæna barabuensis, Winchell, p. 127, Fig. 13, n, o.
Arenicolites woodi, Whitfield, p. 128, Fig. 14, a, b.
Dikelocephalus sp. ?, p. 129, Fig. 15.
lodensis, Whitfield, p. 130, Fig. 16, a, b.
pepinensis, Hall, p. 130, Fig. 16, c, d, e, f.
Aglaspis eatoni, Whitfield, p. 130, Fig. 16, g.
Chariocephalus whitfieldi, Hall, p. 130, Fig. 16, h.
Arionellus convexus, Whitfield, p. 130, Fig. 16, i.
Ptychaspis minuta, Whitfield, p. 130, Fig. 16, j, k.
Illænurus quadratus, Hall, p. 130, Fig. 16, l, m. n, o, p.
Crepicephalus gibbsi, Whitfield, p. 130, Fig. 16, q.
Conocephalites wisconsensis, Owen, p. 131, Fig. 17, a, b, c.
calymenoides, Whitfield, p. 131, Fig. 17, d.
Agnostus josepha, Hall, p. 131, Fig. 17, e, f.
Ellipsocephalus curtus, Whitfield, p. 131, Fig. 17, g.
Agraulos woosteri, Whitfield, p. 131, Fig. 17, h, i.
Pemphigaspis bullata Hall, p. 131, Fig. 17, j.
Climactichnites youngi, Chamberlin, p. 132, Fig. 18.
fosteri Chamberlin, p. 132, Fig. 18.

The species *Orthis remnichia* and *O. sandbergi* are described in 1886 by Prof. N. H. Winchell from the St. Croix sandstone.[1]

In 1890, Mr. C. D. Walcott described the following species from the Upper Cambrian of Wisconsin and Minnesota:[2]

Metoptoma? minneiskensis, p. 267.
? peracuta, p. 267.
Conularia cambria, p. 270.
Spirodentalium, n. gen., p. 271.
Spirodentalium osceola, p. 271.
Ptychoparia connata, p. 272.
pero, p. 274.
Agraulos? thea, p. 277.

RED SANDSTONE OF LAKE SUPERIOR.

On Pl. I C and II, Figs. 1 and 2 of the illustrations in the Geological Report of Wisconsin, Iowa, and Minnesota, 1852, Dr. D. D. Owen figures certain markings he observed on sandstones from the northwest shore of Lake Superior. He considered they probably indicated the remains of fossil sea-weeds or fucoids.

There is a specimen in the collections of the National Museum, labeled "Plants of Lake Superior, D. D. Owen." The specimen looks very much like the sandstones of the interior of Wisconsin, and is covered with casts of annelid trails, more or less crushed and matted down, which gives a resemblance to fucoids. Of traces of life other than that of annelid trails and borings nothing has to my knowledge been made known to the scientific world.

[1] New species of fossils. 14th Ann. Rep. Minn. Geol. Nat. Hist. Surv., 1886, pp. 317-318.
[2] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267-279.

MISSOURI.

The only description of a fossil referred to the Cambrian of Missouri is that of *Lingulella lamborni* by Meek.[1]

EASTERN BORDER OR ADIRONDACK SUB-PROVINCE.

The first notice of anything of an organic nature in the strata now referred to the Potsdam or Upper Cambrian zone, about the Adirondacks, was by Mr. J. H. Steele in 1825, who described certain large calcareous concretions.[2] These were subsequently described in detail by Prof. J. Hall and named *Cryptozoon proliferum*.[3]

The second notice is by Dr. E. Emmons, who states that near Keeseville, in the bottom of the fissure at the high bridge, he found numerous specimens of small bivalve mollusca, a lingula.[4]

Lingula acuminata was described by Mr. T. A. Conrad as occurring in the Calciferous sandrock, and in the table of classification he places it as occurring in the gray Calcareous sandstone at the base of the Lower Silurian above the Cambrian system.[5] It is now known to occur in abundance in association with Dikelocephalus and Upper Cambrian fossils in a calcareous sandrock and limestone, both at Whitehall and in Saratoga County, and in the Potsdam sandstone on Marble River, Franklin County, New York.

In his description of the Potsdam sandstone at Au Sable Chasm, Jefferson County, New York, Dr. Emmons figures and names *Lingula antiqua*.[6] The same woodcut is used by Prof. Hall to illustrate *Lingula acuminata* of Conrad.[7]

In volume I of the Paleontology of New York, Prof. J. Hall defines the genus Scolithus of Haldeman (p. 2), and describes *S. linearis* Haldeman (p. 2); *Lingula prima* of Conrad is described and illustrated; and *Lingula antiqua* is proposed as a new species for the specimen figured by Emmons as *Lingula antiqua* (p. 3). These species are illustrated on Plate I.[8]

Attention was called to the presence of a track and footprint of an animal in the Potsdam sandstone of Lower Canada by Sir W. E. Logan

[1] Notice of a new brachiopod from the lead-bearing rocks at Mine la Motte, Missouri. Phila. Acad. Nat. Sci., Proc., vol. 23, 1871, p. 185.

[2] A description of the Oolitic formation lately discovered in the county of Saratoga, and State of New York. Am. Jour. Sci., vol. 9, 1825, pp. 16–19.

[3] Cryptozoon, n. gen., Cryptozoon proliferum, n. sp. Description of Pl. vi. 36th Ann. Rep. State Mus. Nat. Hist., 1884.

[4] Report of the geologist of the 2d geological district of New York. Second annual report of the Geological Survey of N. Y. Albany, 1838, p. 230.

[5] Second annual report of the paleontological department of the survey, Third annual report of the Geological Survey of New York. Albany, 1839, pp. 63, 64.

[6] Geology of New York, Part 2, comprising the survey of the 2d geological (northern) district. 1842, p. 268, fig. 68.

[7] Geological survey of New York; its influence on the productive pursuits of the community. N. Y. State Agric. Soc. Trans., for 1843, 1844, p. 252.

[8] Paleontology of New York, vol. I, containing descriptions of the organic remains of the lower division of the New York System. Albany, 1847.

in 1851. He described its mode of occurrence and stratigraphic position.[1] This paper was followed by one by Prof. Owen, who refers the tracks to a species of tortoise.[2]

At a meeting of the British Association for the Advancement of Science, held at Ipswich in 1851, Sir W. E. Logan exhibited a slab of sandstone and a cast from a larger one, showing what Prof. Owen had, in a communication to the Geological Society, pronounced to be a track and footsteps of a species of tortoise, thus proving the existence of reptiles at the very earliest period of known animal life.[3]

In describing in 1852 the sandstone occurring in Beauharnois County, Canada, Sir W. E. Logan makes the following observation upon *Scolithus linearis*:[4]

> In this part it [the sandstone] is abundantly marked over considerable surfaces by what the geologists of New York have called *Scolithus linearis*, which consists, where the rock is weathered, of straight, vertical cylindrical holes, of about an eighth of an inch in diameter, descending several inches, and where the rock is unweathered of corresponding solid cylinders, composed apparently of grains of sand, cemented by a slightly calcareous matrix, more or less tinged with peroxide of iron. Mr. Hall and other American geologists include them among the Fucoids of the rock, but they appear to me more like worm holes. In one or two instances I have perceived that the tubes are interrupted in their upward course by a thin layer of sand, of a portion which descends into them and stops them up; and from this it would appear that the cylinders were hollow when the superincumbent sand was spread over them. Whatever may be the origin of the tubes, they strongly mark many beds in the upper part of the sandstone throughout the Canadian portions of its distribution already mentioned; and it is stated by Mr. Hall that the same characteristic accompanies the Potsdam sandstone in New York and Pennsylvania and as far as Tennessee.

He also speaks of the presence of Fucoides and of *Lingula antiqua*. This is followed by a detailed account of the strata containing the footprints described in the same volume by Prof. Owen.

This paper by Mr. Logan was followed by one by Prof. Owen, who described the various footprints and impressions under the following names:[5]

Protichnites septem-notatus, p. 214.
Protichnites octo-notatus, p. 217.
latus, p. 218.
multinotatus, p. 219.
lineatus, p. 220.
alternans, p. 221.

The descriptions are accompanied by admirable illustrations of the varieties designated. He concludes that the impressions appear to have been made by animals allied to Limulus.[6]

---

[1] On the occurrence of a track and footprints of an animal in the Potsdam sandstone of Lower Canada. Quart. Jour. Geol. Soc., London, vol. 7, 1851, pp. 247–250.

[2] Ibid., p. 250–252.

[3] On the age of the copper-bearing rocks of Lake Superior and Huron, etc. British Assoc. Rep. Trans., of sections for 1851–'52, p. 62.

[4] On the footprints occurring in the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc. Lond., Proc., vol. 8, 1852, pp. 200, 201.

[5] Description of the impressions and footprints of the Protichnites from the Potsdam sandstone of Canada. Quart. Jour. Geol. Soc. London, vol. 8, 1852, pp. 214–225.

[6] Op. cit., p. 224.

In 1856 Dr. Emmons published a description of *Lingula prima* Emmons, *Lingula antiquata* Emmons, and *L. acuminata* Conrad. The two latter species are illustrated on Pl. IV, but in the description of the plate the figure of *Lingula antiquata* is called *L. prima* by error.[1]

In 1860, Prof. F. H. Bradley described and illustrated *Conocephalites minutus* from the Potsdam sandstone at Au Sable Chasm, near Keeseville, New York.[2]

The announcement of the discovery of another type of track in the Potsdam sandstone was made by Sir W. E. Logan, in 1860. For this he proposed the name *Climactichnites wilsoni*.[3]

In 1869 Prof. O. C. Marsh described a new species of Protichnites from the Potsdam sandstone of Essex County, New York, naming it *Protichnites logananus*.[4]

As the result of comparative study of different tracks, Dr. J. W. Dawson concluded that Protichnites of Owen was possibly made by some Limuloid crustacean.[5]

From collections made at Keeseville, New York, Messrs. Hall and Whitfield described the genus Palæacmæa, the type species being *Palæacmæa typica* and *Hyolithes gibbosa*.[6]

In 1877 Mr. E. J. Chapman says that the fossil tracks known as Protichnites and Climactichnites are of such a nature that he does not consider them to be of animal origin; and he suggests that they are nothing more than impressions of large fucoids. If this idea be accepted he proposes to change the names to Protichnides and Climactichnides.[7]

From the limestone in Saratoga County, New York, in which Mr. J. H. Steele noticed the large concentric concretions, Mr. C. D. Walcott described in 1879 the following species:[8]

Platyceras minutissimum, p. 129.
Metoptoma cornutiforme, p. 129.
Conocephalites calciferus, p. 129.
Conocephalites harttii, p. 130.
Ptychaspis speciosus, p. 131.

The presence of a species closely allied to *Bathyurus armatus* of Billings was noticed; also Stromatopora sp. ?, *Lingula acuminata*, *Metop-*

[1] American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. Albany, 1856, vol. 1, pt. 2, pp. 202, 203.

[2] Description of a new trilobite from the Potsdam sandstone. Am. Jour. Sci., 2d ser., vol. 30, 1860, p. 241.

[3] On the track of an animal lately found in the Potsdam formation. Canadian Nat., vol. 5, 1860, pp. 282–285.

[4] Description of a new species of Protichnites from the Potsdam sandstone of New York. Am. Jour. Sci., 2d ser., vol. 48, 1869, pp. 46–49.

[5] Impressions and footprints of aquatic animals and imitative markings on Carboniferous rocks. Am. Jour. Sci., 3d ser., vol. 5, 1873, p. 17.

[6] Notice of two new species of fossil shells from the Potsdam sandstone of New York. 23d Rep. New York State Mus. Nat. Hist., 1873, p. 242.

[7] On the probable nature of the supposed fossil tracks known as Protichnites and Climactichnites. Canadian Jour. Sci., Lit. and Hist., new series, vol. 15, 1877, p. 490.

[8] Descriptions of new species of fossils from the Calciferous formation. 32d Rep. N. Y. State Mus. Nat. Hist., 1879, pp. 129–131.

toma simplex, Murchisonia sp. ?, and a Lamellibranchiate shell. The fauna was correlated with that of the Potsdam sandstone of Iowa and Wisconsin, although the rocks were referred to the Calciferous formation. This reference was corrected in 1884.[1]

In 1883, Mr. W. F. Ferrier called attention to the presence of tracks on the Potsdam sandstone at the head of Au Sable Chasm in Essex County, New York. They were referred to the genus Gyrichnites of Whiteaves.[2] Later the tracks discovered by Mr. Ferrier were made the subject of a note by Sir J. W. Dawson, who proposed the generic name of Clydichnites for them.[3]

In a note on some obscure organisms in the roofing slates of Washington County, New York, Prof. James Hall redescribes *Buthotrephis ? asteroides* Fitch as *Dactyloidites bulbosus*.[4]

A revision of the fauna occurring in the limestone beds of Saratoga County was made by Mr. C. D. Walcott in 1886, and the following list was published:[5]

NEW YORK.	WISCONSIN.
Cryptozoa proliferum	
Lingulepis acuminata	Lingulepis pinnæformis.
Platyceras minutissimum	Platyceras minutissimum.
Platyceras hoyti	
Metoptoma cornutiforme	Metoptoma cornutiforme.
simplex	
Billingsia saratogensis	
Matthevia variabilis	
Dicellocephalus hartti	Dikelocephalus pepinensis.
speciosus	lodensis.
Ptychoparia calcifera	Ptychoparia wisconsensis.
(A.) saratogensis	oweni (of Hall).

As the result of the comparison of an extended series of specimens from the Potsdam sandstone of Buckingham, Quebec, Messrs. Ami and Sowter concluded that *Scolithus linearis* and *S. canadensis* were identical species; the main differences existing between the two being principally in the preservation, *S. canadensis* occurring in hollow tubes or burrows, while *S. linearis* occurs as casts of the interiors of burrows or holes.[6]

In 1890 Mr. C. D. Walcott described[7] the following species from the limestone in the vicinity of Saratoga Springs, New York:

Platyceras hoyti, p. 268.
Trochus ? saratogensis, p. 268.
Agraulos saratogensis, p. 276.

---

[1] Potsdam fauna at Saratoga, New York. Science, vol. 3, 1884, pp. 136, 137.

[2] Notes on a fossil track from the Potsdam sandstone of northern New York State. Canadian Nat. new ser., vol. 10, 1883, pp. 466, 467.

[3] Impressions on Potsdam sandstone. Science, vol. 1, 1883, p. 177.

[4] Note on some obscure organisms in the roofing slates of Washington County, New York. 39th Rep. N. Y. State Mus. Nat. Hist., 1886, p. 160, pl. 11, fig. 1, 2.

[5] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 21.

[6] Report of the geological branch [of Ottawa Field Naturalists' Club]. Ottawa Naturalist, vol. 1, 1887, pp. 96, 97.

[7] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus., Proc., vol. 13, 1890, pp. 276–279.

WESTERN BORDER OR ROCKY MOUNTAIN SUBPROVINCE.

In a letter from Messrs. Meek and Hayden to Lieut. G. K. Warren, dated February 8, 1858, attention is called to the identification of fossils from a sandstone in the Black Hills equivalent to the Potsdam sandstone of the New York series. They recognized Lingula, Obolus?, and fragments of trilobites, belonging to species known to occur in the Potsdam formation in Wisconsin and Minnesota.[1] This notice was followed in 1861 by the publication of the first description of the Cambrian fauna of the Rocky Mountains. The new species described but not illustrated include *Obolella nana*, *Theca* (*Pugiunculus*) *gregaria*, and *Arionellus* (*Crepicephalus*) *oweni*.[2] The descriptions of the species were republished in 1862, in the American Journal of Science, in connection with figures illustrating them. The last species is described as *Arionellus? oweni*. There were also identified from the same horizon *Lingula prima* Conrad and *Lingula antiqua* Hall.[3]

The Black Hills fauna was again described by Messrs. Meek and Hayden in 1864, in their account of the paleontology of the Upper Missouri. *Lingula antiqua*, mentioned in their letter of 1858, is identified as *Lingulepis pinnaformis* Owen (p. 2), and the name *L. dakotensis* proposed in the event of the shell being subsequently determined to be a new species (p. 3). A description and illustration is also given of *Lingulepis prima* Conrad (p. 3), *Obolella nana*, M. & H. (p. 4), *Theca gregaria*, M. & H. (p. 5), *Agraulos oweni*, M. & H. (p. 9), (*Arionellus* (*Crepicephalus*) *oweni*, of the paper of 1861), and an undetermined species of Agraulos (p. 10). All of the species are referred to the Potsdam or Primordial sandstone.[4]

In 1876, when reporting upon the fossils collected by Captain Ludlow's expedition to the Yellowstone National Park, Prof. R. P. Whitfield described two species that are now referred to the Upper Cambrian zone, *Crepicephalus* (*Loganellus*) *montanensis* and *Arionellus tripunctatus*, referring them to the limestone of the Potsdam group overlying the quartzite near Camp Baker.[5]

A preliminary report on the paleontology of the Black Hills by Prof. R. P. Whitfield contains a description of *Palæochorda prima*, *Palæophycus occidentalis*, *Lingulepis cuneolus*, *L. perattenuatus* *Crepicephalus* (*Loganellus*) *centralis*, and *C.* (*L.*) *planus*. All of these species are referred

[1] Fossils of Nebraska. Letter from F. B. Meek and F. V. Hayden. Am. Jour. Sci., 2d ser., vol. 25, 1858, p. 439.

[2] Descriptions of new Lower Silurian (Primordial), Jurassic, Cretaceous, and Tertiary fossils, collected in Nebraska, with some remarks on the rocks from which they were obtained. Phil. Acad. Sci., Proc., vol. 13, 1861, pp. 435, 436.

[3] The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 73, 74.

[4] Paleontology of the Upper Missouri; a report upon collections made principally by the expeditions under command of Lieut. G. K. Warren in 1855 '56. Invertebrates. Smithsonian Contributions No. 172, 1864, pp. 1–10.

[5] Descriptions of new species of fossils. Report of a reconnaissance from Carroll, Montana Terr., on the Upper Missouri, to the Yellowstone Park and return, made in the summer of 1875 by Wm. Ludlow, 1876, p. 141.

to the Potsdam formation of the Black Hills of Dakota.[1] In the final report, which appeared in 1880, the species described in the preliminary report are illustrated, and descriptions and illustrations given of *Palæophycus* sp. undet., *Arenocolites* sp. undet. (p. 333), *Lingulepis pinnaformis* (p. 331), *Lingulepis dakotentis* (p. 337), *Obolus? pectenoides* (p. 338), *Obolella polita* (p. 339), *Obolella nana* (p. 340). In the preliminary remarks to the paper it is stated that the horizon of the Potsdam formation of the Black Hills appears to be, so far as the fossils will serve to determine, about the same as that of Wisconsin and the neighboring States.[2]

The only fossils of the Cambrian fauna identified in Colorado are a species of Dikelocephalus from Quandary Peak of the Mosquito Range,[3] and the Lingulepis found in the Trout Creek section (p. 62).

In 1890 Mr. C. D. Walcott[4] described three species from the Upper Cambrian of the Black Hills of Dakota. They were *Hyolithes newtoni* (p. 270), *Ptychoparia vacuna* (p. 275), and *P. (Liostracus) panope* (p. 275).

TEXAS.

The first notice of the presence of a fauna in Texas subsequently assigned to the Cambrian is by Dr. Roemer in 1849. A description of *Lingula acutangula* (p. 420) and *Pterocephalia sancti-sabæ* (p. 421) is given by him in that year without illustrations.[5]

In his more extended work on the geology of central Texas he describes and illustrates *Lingula acutangula* (p. 90), *Pterocephalia sancti-sabæ* (pp. 92, 93), and the genus *Pterocephalia* (p. 93). He also illustrates the head of a trilobite, allied to Arionellus, and the pygidium of another species, on Table XI.[6]

The primordial character of the fauna referred to the Silurian by Dr. Roemer was announced by M. J. Barrande the following year. He compared it with the fauna of the Potsdam sandstone of New York and Wisconsin.[7]

As geologist of the State of Texas, Dr. B. F. Shumard described in 1861, the strata referred to the Potsdam sandstone. Of the fossils collected he describes as new;

Agnostus coloradoensis, p. 218.
Arionellus (Bathyurus) texanus, p. 218.
planus, p. 219.

---

[1] Preliminary report on the Paleontology of the Black Hills. U. S. Geol. and Geog. Surv. of the Rocky Mountain region, 1877, pp. 7-11.

[2] Paleontology of the Black Hills of Dakota. Report on the geology and resources of the Black Hills of Dakota, 1880, pp. 329-344.

[3] Geology and Mining Industry of Leadville, Colorado. U. S. Geol. Surv., Monograph vol. 12, pt. 1, 1886, p. 60.

[4] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267-279.

[5] Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes nach eigener Beobachtung geschildert. Bonn, 1849, pp. 420-421.

[6] *Die* Kreidebildungen von Texas und ihre organischen Einschlüsse. Bonn, 1852.

[7] (Silur-Gebilde in Texas und am Oberen See.) Neues Jahrbuch für Miner, 1853, pp. 446, 447.

Conocephalites depressus, p. 219.
billingsi, p. 220.
Dikelocephalus roemeri, p. 220.
Discina microscopica, p. 221.

and he mentions Camerella sp. ?, and Capulus sp. ? (p. 221).[1] He correlates this fauna with that provisionally designated as "being very analogous to the Potsdam of Iowa, Wisconsin, and Minnesota,"[2] and refers it to the Potsdam sandstone.

In the collections obtained by Mr. C. D. Walcott in his reconnaissance of the central area of Texas the following species have been identified:

Eocystites sp. ?
Lingula acuminata, Conrad.
perattenuata, Whitf.
Obolella polita, Hall.
Triplesia primordialis, Whitf.
Orthis coloradoensis, Shumard.
remnichia, Winchell.
Platyceras texanum, Walcott.
Bellerophon antiquatus, Whitf.
Dikelocephalus minnesotensis, Owen (?).
belli, Billings.
Ptychaspis granulosa, Owen.
Chariocephalus tumifrons, H. & W.
Ptychoparia occidens, Walcott.
affinis, Walcott.
burnetensis, Walcott.
llanoensis, Walcott.
? metra, Walcott.
pero, Walcott.
? urania, Walcott.
similis, Walcott.
patersoni, Hall.
perseus var., Hall.
wisconsensis, Owen.
Agraulos convexus, Whitf.
Agraulos ? sp. ?
Illænurus dia, Walcott.

This fauna will be illustrated in connection with a review of the Upper Cambrian fauna of North America now in course of preparation.

In 1890 Mr. Walcott[3] described the following new species from Upper Cambrian strata of Burnet and Llano Counties:

Platyceras texanum, p. 268.
Ptychoparia burnetensis, p. 272.
llanoensis, p. 272.
? metra, p. 273.
pero, p. 274.
? urania, p. 274.
Illænurus ? dia., p. 277.

ARIZONA.

The paleontologic work on the Cambrian fauna found in Arizona has, thus far, been confined to the identification of the species discovered in the Tonto formation of the Grand Cañon. A preliminary study of the fauna has been made and drawings prepared of the species, but up to the present time nothing has been published in relation to them.

[1] The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci. 2d ser., vol. 32, 1861, pp. 213–221.
[2] Op. cit., pp. 217, 218.
[3] Description of new forms of Upper Cambrian fossils. U. S. Nat. Mus. Proc., vol. 13, 1890, pp. 267–279.

CHAPTER III.

NOMENCLATURE EMPLOYED IN THE DESCRIPTION OF THE FORMATIONS.

Several considerations are to be borne in mind relative to geologic nomenclature:

(*a*) The name in itself is nothing unless it conveys to the mind a clear impression of what it refers to and enables the student to make a correlation between its entity and some other entity that has another terminology.

(*b*) Priority of discovery and naming should be sustained by the proof of the accuracy of the original observations, the latter to be judged by the testimony of the formations in the areas where they were first made. If the original proposer of a name bases it upon such errors of observation and interpretation that subsequent observers can not verify his work, and the name can be used only by dropping a name proposed as the result of accurate observation and definition, the latter should be retained and the law of priority should not be used to bolster up an indefinite term.

(*c*) Long use of, and the general acceptance of, a well defined term by the scientific world gives that term a standing that even the claims of a half understood, badly defined term supported by priority should not displace. This may be called the law of usage.

(*d*) From the fact that all the strata of the geologic series do not exist in any one geologic province and that unconformities between different portions of them are not contemporaneous in all provinces, it necessarily follows that the rock series of any one geologic province can not possibly be the chronological equivalent of the rock series of other provinces. Overlappings of series of different chronologic age must occur, and it is therefore impossible for any one geologic province to afford a nomenclature that is applicable to the geologic provinces of the entire world or to the entire geologic series.

(*e*) Each geologic province should have a nomenclature denoting by name each formation contained in it and, if necessary, the names to be applied to the groupings of the formations; but, if practicable, the formations and the grouping of formations should be referred to some position within the larger composite groups. For instance, the Potsdam standstone of New York, the Saratoga County limestone, and the Dutchess County limestone are lithologically distinct formations, but they are grouped under the Upper Cambrian terrane as a portion of the Cambrian group.

This method necessitates the multiplication of names, but if it insures accuracy of statement and meaning it is much better than the use of a few old names that have been established in some one geologic province and extended over other upper Cambrian formations in other geologic provinces that can not be proved to be identical or synchronous.

(*f*) The study of the serial relations among rocks by the modern method is of as much importance as that of the specific relations of distinct horizons or of particular formations. The serial relations of one series of rocks in one province can be compared with the serial relations of another group in another province; but the two should receive separate names and be grouped under the greater series to which they belong. For instance, the Trenton series of New York may be compared with the Lebanon series of Tennessee and united as a portion of the Lower Silurian (Ordovician) and respectively compared with the same portion of the Lower Silurian (Ordovician).

(*g*) If it is found that the strata included in a named formation, terrane, or group embraces portions of other formations, terranes, or groups it is allowable to remove portions of such formations, terranes, or groups and still apply the original name, if the portion remaining is distinct or was first described and included under the name.

(*h*) Geologic nomenclature should, in all its parts, be the natural expression of the inter-relationships and mutual subordination of the facts it is the especial aim to associate and systematize.[1]

CAMBRIAN.

The term Cambrian was first introduced to the attention of geologists at the Dublin meeting of the British Association for the Advancement of Science in August, 1835. A joint paper was read by Prof. Adam Sedgwick and R. I. Murchison, entitled "On the Silurian and Cambrian Systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales." An abstract of this paper appeared in the account of the proceedings of the British Association published in the Edinburgh New Philosophical Journal for April–October, 1835, page 390. In this the name Cambrian is spelled Cumbrian, probably by a typographical error. The paper appeared in 1836, in volume 5 of the Reports of the Association. In the account of the Transactions of the Sections it says:[2]

Prof. Sedgwick commenced by pointing out the imperfection of the sections exhibited in the north of England and some portions of north Wales, in consequence of the entire want of continuity between the Carboniferous series and the interior schistose group. * * * Prof. Sedgwick then described in descending order the group of slate rocks as they are seen in Wales and Cumberland. To the highest he gave the name of *Upper Cambrian* group. It occupies the greatest part of the chain of the Berwyns, where it is connected with the Llandeilo flags of the Silurian system, and

[1] On the tripartite classification of the Lower Paleozoic rocks; Charles Lapworth, Geol. Mag., new series, dec. II, vol. 6, 1879, p. 11.

[2] Brit. Assoc. Report for 1835, part 2, Trans. of Sections, 1836, p. 60.

is thence expanded through a considerable portion of south Wales. In one part of its course it is based on beds of limestone and calcareous slate, but on the whole it contains less calcareous matter than the Silurian system and has fewer organic remains. Beds of good roofing slate occur, and a perfect slaty cleavage is often observed in it transverse to the stratification, but other parts of it are of a coarse mechanical texture. To the next inferior group he gave the name of *Middle Cambrian*. It composes all the higher mountains of Caernarvonshire and Merionethshire, and abounds in fine roofing slate, alternating with and apparently passing into irregularly interstratified masses of porphyry. Some portions of it are coarse and mechanical, and it contains (for example at the top of Snowdon) a few organic remains and a few samples of highly calcareous slates, but no continuous beds of limestone. The same group, with the same mineral structure, and in the same position, but without organic remains, is greatly developed in Cumberland. The *Lower Cambrian* group occupies the southwest coast of Caernarvonshire and a considerable portion of Anglesea; it consists chiefly of chlorite schist, passing here and there into mica schist and slaty quartz rock and contains subordinate masses of serpentine and white granular limestone. It contains no organic remains.

In this first description, Archean rocks are included in the lower division; the Middle Cambrian embraces the roofing slates, and the Cambrian group as now generally accepted; while the Upper Cambrian included much of the Lower Silurian of Sir R. I. Murchison, or the Ordovician of Prof. Charles Lapworth.

At a meeting of the Geological Society of London in the spring of 1838, Prof. Sedgwick read a paper entitled "A Synopsis of the English series of stratified rocks inferior to the Old Red sandstone, with an attempt to determine the successive natural groups and formations."[1] When describing the sections of North Wales, etc., the chlorite slates, quartz rock, and mica slates of Anglesea and Caernarvonshire are not included in the Cambrian as was done in 1835.[2] The Lower Cambrian system includes the old slate series of Caernarvonshire and Merionethshire, and ends with the calcareous beds, which range from Bala to the neighborhood of Dinas Mowddy.

The next group, the Upper Cambrian series, commences with the fossiliferous beds of Bala. It includes all the higher portion of the Berwyns, and all the slate rocks of South Wales, which are below the Silurian system. * * * Many of the fossils are identical in species with those of the lower division of the *Silurian system*, nor have the true distinctive zoological characters of the group been well ascertained.

In this arrangement, the Lower Cambrian of 1835 is referred to the primary stratified group, to which he gave the provisional name of Protozoic.[3]

It is further stated that at the north end of the Berwyn chain the Upper Cambrian appears to pass by insensible gradations into the lower division of the upper system, the Caradoc sandstone. Prof. Sedgwick does not appear to have been aware at this time that his Bala series was a portion of Murchison's Lower Silurian, as described by the latter in 1835.

Many geologists have insisted upon restricting the Cambrian to the Lower Cambrian of the scheme of 1835, which Prof. Sedgwick cut off

[1] Proc. Geol. Soc., London, vol. 2, 1838, pp. 675–685. [2] Op. cit., p. 685. [3] Op. cit., p. 684.

in the revision of 1838. It is also well to notice that the Cambrian of 1838 includes exactly the same representative formations as Emmons's Taconic System of 1842–1860, or the Cambrian and Lower Silurian (Ordovician) as now known.

In 1852 we find the Lower Cambrian divided into the Festiniog group above and the Bangor below. The Bangor group is composed of the Llanberris slates and Harlech grits; and the Festiniog group of the Lingula flags, Tremadoc slates, and Arenig slates and porphyry, the whole having a thickness of 10,000 feet. The Upper Cambrian includes the Bala group, which was divided into the Lower and Upper Bala, with a thickness of 8,000 feet. Above this the Caradoc sandstone, limestone, and shale of the Silurian occur with a thickness of 1,500 feet.[1]

In the paper on the Caradoc sandstone of Shropshire, by Messrs. J. W. Salter and W. T. Aveline, it is stated that the fossils of the supposed typical Caradoc sandstone are identical in species, and in association and proportionate numbers of the prevailing species, with those of the Bala group; and there is no admixture of other or new forms, or of those characteristic of higher parts of the system.[2] By priority of definition and description, the Llandeilo and Caradoc beds belong to Murchison's Silurian system; and the Bala series of Sedgwick are stratigraphically and paleontologically the equivalents of the Llandeilo and Caradoc series. They were fairly removed from the Cambrian system by the work of Messrs. Murchison, Sedgwick, and Salter; and in 1854 the Cambrian system included of the original Cambrian the middle member only, the lower division having been removed by Prof. Sedgwick in 1838. The distinguished founder of the Cambrian system did not admit the exclusion of the Bala series from the Cambrian, but with all the facts assembled, as in a recent paper by Prof. J. D. Dana,[3] I think we are compelled to restrict the Cambrian to the original middle division.

The last tabulation given by Prof. Sedgwick of his Cambrian system appeared in the preface of Mr. J. W. Salter's Catalogue of Cambrian and Silurian Fossils in 1873, as follows:[4]

- Cambrian:
  - Upper
    - Upper Bala.
    - Middle Bala.
    - Lower Bala.
  - Middle
    - Arenig or Skiddaw.
    - Tremadoc.
    - Ffestiniog.
    - Menevian.
  - Lower
    - Harlech.
    - Bangor.
    - Longmynd.
    - Llanberris.

[1] On the classification and nomenclature of the Lower Paleozoic rocks of England and Wales. Quart. Jour. Geol. Soc., London, vol. 8, 1852, p. 147.

[2] On the "Caradoc Sandstone" of Shropshire. Quart. Jour. Geol. Soc., London, vol. 10, 1853, p. 63.

[3] Sedgwick and Murchison; Cambrian and Silurian; Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 167–180.

[4] (On the classification of the Cambrian rocks). "Preface to a Catalogue of the Collection of Cambrian and Silurian fossils contained in the Geological Museum of the University of Cambridge," by J. W. Salter, 1873, p. xv.

With the exception of the Bala and Arenig series the system is essentially the same as that generally accepted by the English geologists at the present day.

As geologist of Tennessee, Dr. Gerard Troost read Sir R. I. Murchison's Siluria, and also the observations of Prof. Sedgwick on the Cambrian rocks of Wales. Discussing the changes in nomenclature made necessary in expressing the views of Messrs. Murchison and Sedgwick, he says in 1841:[1]

After having pointed out, in my last report, the line of junction of the primordial or crystalline rocks in East Tennessee, I mentioned that the country west of the line which separates Tennessee from the State of North Carolina is composed of graywacke, slate, limestone, etc. All this country, according to the views of Murchison and Sedgwick, belongs to a new division, which they call the *Cambrian system*.

He then proceeds to describe the geographic distribution of the rocks that he referred to the Cambrian system, identifying the series in Tennessee with that of Wales entirely upon its lithologic characters and the absence of organic remains, and from the fact of its being succeeded by a series of limestones from which he obtained and identified Silurian fossils.

The presence of the equivalent of the Cambrian system in America was clearly recognized by Dr. E. Emmons, who, in 1844, wrote:

There are, however, if I understand Mr. Sedgwick and Mr. Murchison, rocks still lower; those which are now considered by them as metamorphic. They are the lower masses which I considered as equivalent to the Taconic rocks; the Lower Cambrian of Sedgwick, and not the Upper, which latter I proved to belong to the New York system. That the Taconic slate is precisely that in which the *Nereites* in Wales occur, there is not the slightest doubt in my own mind, and this is that part of the Taconic system which we can see lying unconformably beneath the oldest member of the New York system, and hence of the Silurian also. I know not, however, whether in Wales the same limestones, slates, and quartz rocks are to be found which we have here, and which are the oldest parts of the Taconic system. These are facts to be determined. Their non-existence in Wales, however, does not destroy the system. Very important members are known there, and should the lower slates and quartz be found wanting, it only proves the absence of that development which is so well known here in New York, Massachusetts, Vermont, and Maine, and I may add, in Michigan also.[2]

Under the influence of the publications of Sir R. I. Murchison, American geologists, other than Drs. Troost and Emmons and the latter's followers, classified all the Lower Paleozoic rocks under Lower Silurian, entirely ignoring Cambrian except to state that it was equivalent to the Lower Silurian. In 1872, however, Dr. T. S. Hunt published his history of the names Cambrian and Silurian in geology, advocating the recognition of the term "Cambrian."[3]

[1] Sixth annual report of the geological survey of Tennessee by the State geologist. Nashville, 1841, p. 171, doc. ed., p. 4 of special ed.

[2] The Taconic System, 1844, p. v.

[3] Canadian Naturalist, new ser., vol. 6, 1872, pp. 281-312, 417-448. Geological Magazine, vol. 10, pp. 385-395, 453-461, 504-510, 561-566, 1873.

The view of Dr. Hunt was concurred in by Sir J. W. Dawson, who in 1872 wrote as follows:

I concur in the view that it may well have the name *Siluro-Cambrian*, while the name Cambrian or Primordial will remain for those great and important fossiliferous deposits extending downward from the Potsdam in America and the Tremadoc in England, and constituting an imperishable monument to the labors of Sedgwick and Barrande.[1]

A notice of the proposed change from "Potsdam or Primordial" of the first edition of Dana's Manual of Geology to "Primordial or Cambrian" in the second edition, was published in 1874;[2] and the term was used in a subordinate sense in another edition of the Manual of Geology (1876) as a subdivision of the Lower Silurian (p. 163).

The term "Cambrian" came into general use in the Canadian and Fortieth Parallel Surveys and in the U. S. Geological Survey in 1882. With the exception of a few that prefer to use Taconic, the term is generally employed by geologists of all countries.

Most of the English geologists of the present time draw the line between the Cambrian and Silurian at the summit of the Tremadoc and the base of the Arenig terranes. From a study of the list of genera and species of the fauna of the Lower and Upper Tremadoc slates, I think that the line of demarkation between the two systems would naturally fall between these two subdivisions of the Tremadoc. The fauna of the Lower Tremadoc, in its general facies, is essentially the type of the Cambrian fauna, and there are only a few genera and species more characteristic of the Silurian. The large fauna of the Upper Tremadoc slate is characteristic of the Lower Silurian and the presence of a few genera and species of essentially Cambrian type are not sufficient to include it in the Cambrian. The fact that there is a slight unconformity at the summit of the Tremadoc and the base of the Arenig is not of sufficient general importance to warrant the placing of the line of demarkation between the groups at this horizon.

In a table showing the classification of the British sedimentary rocks, by Prof. A. J. Jukes Brown,[3] the Tremadoc slates are placed in a stage between the Cambrian and Ordovician.

This view of the Tremadoc slates was held by Mr. J. W. Salter,[4] who wrote:

But a few words must be said about this band of slate, which so intimately connects the Lingula flags below with the rocks above, and which is nevertheless so distinct in fossil characters from either.

[1] Canad. Nat., new ser., vol. 7, 1873, p. 7.

[2] Dana, J. D. Reasons for some of the changes in the subdivisions of geological time in the new edition of Dana's Manual of Geology. Am. Jour. Sci., 3d ser., vol. 8, 1874, p. 213.

[3] The classification of stratified rocks. Geol. Mag., new ser., dec. III, vol. 2, 1885, p. 297.

[4] Memoirs of the Geological Surveys of Great Britain. Geology of North Wales, second edition, 1881, p. 355.

Dr. Henry Hicks[1] says of it:

The Tremadoc group, therefore, may be said through many of its types of fossils to link the Cambrian and the overlying Ordovician (Lower Silurian) formations together, while it yet marks very distinctly the horizon in which all the truly characteristic types in the Primordial faunas are lost.

TACONIC.

The first proposition to apply the name Taconic to a system or series of rocks is found in a gazetteer of the State of New York, published in 1842.[2] The article is unsigned, but it bears internal evidence of having been written by Dr. Ebenezer Emmons as his first presentation of the views which were more fully elaborated and published later in the same year. He describes the Taghkanic range, and states that the rocks composing the same are situated between the gneiss of Hoosic Mountain on the east and the slates of the transition on the west; that they bear a very close resemblance to the primary on the east, and, on the other hand, a great similarity to the transition slates on the west.[3]

He says:

It is not proposed in this plan to separate these rocks from the primary, but to consider them as belonging to the upper portion and to speak of them as the Taghkanic rocks, or perhaps as the Taghkanic system. * * * Considering them for the present as belonging to the upper portion of the primary, the Taghkanic rocks will be composed, first, of a peculiar talcose slate, or a magnesian slate in part; in other parts it is plumbaginous, which strongly soils the fingers. * * * Second, of white, gray, and clouded limestone varying in texture from fine to coarse granular, often interlaminated with slate, the latter often merely coloring the limestone so as to impart the clouded appearance. * * * Third, of granular quartz, or a sandstone generally siliceous and of a brown color.[4]

In the concluding remarks on the Taghkanic system, we read:

On the whole, in regard to those rocks we have denominated "Taghkanic," we believe they ought to be separated from those on the east, being, as a whole, clearly distinct from them.[5]

A second memoir appeared in 1842, in which the term "Taghkanic" is changed to Taconic, and a detailed description given of the geographic distribution and character of the rocks forming the Taconic system. A typical section is presented with the following comment:[6]

The following section, extending from Petersburgh, Rensselaer County, to Adams, Massachusetts, embraces all the rocks in this system. Its direction is nearly east and west, or perpendicular to the strike of the system over which it passes.

---

[1] On some recent researches among Lower Paleozoic rocks in the British Islands. Proc. of the Geologists' Association, vol. 7, p. 9.

[2] Topography, geology, and mineral resources of the State of New York. Gazetteer of the State of New York, by James Disturnell. Albany, 1842, pp. 5–25.

[3] Op. cit., p. 11.

[4] Op. cit., p. 11.

[5] Op. cit., p. 12.

[6] Geology of New York, part 2, comprising the survey of the 2d geological (northern) district, 1842, p. 145.

In 1844, a separate memoir[1] was published in which a great addition, was made to the Taconic system west of the Petersburg end of the section of 1842. This addition was in 1856[2] separated as the Upper Taconic.

TACONIAN.

This name was proposed by Dr. T. S. Hunt, in 1877, to include the Lower Taconic of Dr. Emmons,[3] or the Granular Quartz, Berkshire limestone, and Taconic slates of the latter's typical Taconic section of 1842. At the time of the proposal of the name the author was uncertain whether the strata included under it should be referred to the basal beds of the Cambrian or to a pre-Cambrian system of rocks.

In a later paper he refers the Taconian system of the Appalachians to a pre-Cambrian horizon as compared with the Cambrian rocks from that region. This is stated by him as follows: "This Appalachian-Cambrian series is wholly uncrystalline, and is separated from the Taconian by a stratigraphical break, and by a great interval of time, which includes the Keweenian period."[4] As we now know that the Granular Quartz is characterized by the Lower Cambrian or Olenellus fauna, the Berkshire or Stockbridge limestone by the Chazy-Trenton and perhaps at its base by an Upper Cambrian fauna, and the original Taconic slate of the Lower Taconic of Dr. Emmons is correlated by its stratigraphic position with the Hudson shales, the term Taconian ceases to be of value in geologic nomenclature.

PRIMORDIAL.

This name was used by M. J. Barrande to designate the First fauna, in contradistinction to the Second and Third.[5]

The name was applied at first to the fauna, but, in 1854, in the first edition of "Siluria," Sir Roderick Murchison designated the formation containing the Primordial fauna as the Primordial Silurian, dividing the Silurian into the Upper Silurian, the Lower Silurian, and the Primordial Silurian. The use of the latter term has been advocated more or less by those who oppose the use of the term Cambrian; but the name Primordial is now rarely used except when mentioning the First fauna of Barrande.

---

[1] The Taconic System; based on observations in New York, Massachusetts, Vermont, and Rhode Island. Albany, 1844, pp. i–vii, 67.

[2] Emmons, Ebenezer. American Geology, containing a full statement of the principles of the science, with full illustrations of the characteristic American fossils. Albany, 1856, vol. 1, pt 2, pp. 49–66.

[3] On the geology of the Eozoic rocks of North America. (Abstract). Boston Soc. Nat. Hist., vol. 19 1878, p. 278.

[4] Hunt, T. Sterry. The Taconic Question in Geology. Mineral Physiology and Physiography. A second series of chemical and geological essays. With general introduction. 1886, p. 677.

[5] Système Silurien du centre de la Bohème, vol. 1, 1852, p. 88.

POTSDAM.

There are several early references to a sandstone occurring at the base of the section in the Upper Mississippi Valley and about the Adirondack Mountains in New York; but it was not until 1838 that it was well defined and given a distinct name. This was done by Dr. E. Emmons. In describing this sandstone, Dr. Emmons says:[1]

I shall not enter upon its geological relations any farther than to state that, in Potsdam and other towns in which it appears, it uniformly rests on the primary strata; and in no part of the county is there any rock which interposes itself between it and the primary, so that it appears here as the oldest representative of the transition series. The identification of this rock with the sandstones along the southern border of Lake Ontario will be a matter of some difficulty. It is geologically below the transition limestone, and never in the northern district alternates with it, but always holds the relation of an inferior rock. * * *

This rock is a true sandstone, of a red, yellowish red, gray, and grayish white colors. It is made up of grains of sand, and held together without a cement. Intermixed with the siliceous grains are finer particles of yellowish feldspar, which do not essentially change the character of the sandstone, but they show the probable source from which the materials forming it were originally derived, viz, some of the varieties of granite.

On the Lake Champlain side of the Adirondacks it is described as follows:

Its position is evidently beneath the transition limestone and calciferous sandrock. It is very deficient in organic relics, though not entirely destitute of them. It is unnecessary to repeat what has already been said of this rock; it is purely quartzose or siliceous in its composition and finely stratified. It dips to the northeast at Port Kent at an angle varying from 5° to 10°. The places where it occurs along Lake Champlain are indicated on a map of a part of this [Clinton County], to which I refer the reader. This rock at Keeseville has been rent in the most remarkable manner; several fissures, the principal one of which extends nearly a mile, and through which the Au Sable flows, have been opened by some convulsion in nature to the depth, in some places, of a hundred feet and from five to twenty wide. Near the bottom of the fissure at High Bridge, as it is called, I discovered numerous specimens of a small bivalve mollusca, a lingula. I found, also, on examination, that the same fossil occurred through an extent of 70 feet at least, and so far as I could discover, it was the only fossil inclosed in the rock. It is extremely thin and delicate, yet the shell is perfectly preserved, and is probably one of the oldest inhabitants of the globe, as the rock in which they occur is the oldest of the transition series.[2]

The name "Potsdam sandstone" was quickly accepted by the New York State geologists, incorporated in their annual reports, and used in the final report on the geology of the State. The extension, by correlation, of the name to the Southern Appalachians, through Pennsylvania, Virginia, North Carolina, Tennessee, and Alabama; westward through the Mississippi Valley and the Rocky Mountains, and north into Canada, and down the St. Lawrence Valley, rapidly followed, until the name Potsdam is now used to typify the Upper Cambrian zone in all parts of America.

[1] Report of the geologist of the 2d geological district of New York. Second annual report of the Geological Survey of N. Y. Albany, 1838, pp. 214, 215.

[2] Op. cit., p. 230.

ST. CROIX.

The name St. Croix was proposed by Prof N. H. Winchell in 1873 for the fossiliferous sandstone beneath the Lower Magnesian limestone of the Mississippi Valley. The reason given is that the sandstone identified by Dr. D. D. Owen as the Potsdam sandstone is unconformably superjacent to a series of quartzites in Wisconsin and Minnesota that are the true equivalents of the Potsdam sandstone of New York.[1]

The presence of the same fauna in the typical Potsdam sandstone on the northern side of the Adirondack Mountains as that found in the upper sandstone of St. Croix Falls negatives this view and correlates the sandstones that are unconformably superjacent to the lower quartzites with the typical Potsdam, and refers the lower quartzites to the Algonkian. The name St. Croix, however, is retained for the fossiliferous Cambrian sandstones of the upper Mississippi Valley in Wisconsin, Iowa, and Minnesota.

MADISON.

The name Madison sandstone was proposed by Prof. R. D. Irving,[2] in 1877, for a band of sandstone consisting, in large part, of nearly pure white quartz sand, with a thickness of 35 to 50 feet, and lying between the base of the Magnesian limestone of the Lower Silurian (Ordovician) and the Mendota limestone in Wisconsin.

MENDOTA.

This name was proposed by Prof. R. D. Irving, in 1877, for a calcareous stratum near the upper portion of the "Potsdam" formation of Wisconsin. It is formed of alternating sandy and calcareous material that, in the upper portion, is almost a well marked and very persistent yellow limestone layer, with a thickness of 30 feet.[3]

TONTO.

This name was applied by Mr. G. K. Gilbert, in 1874,[4] to a series of sandstone and shale between the subjacent granite and the superjacent massive limestones that occur in the section at the mouth of the Grand Cañon of the Colorado River, Arizona. He considered the formation of Primordial age, and it has since been found to contain an Upper Cambrian fauna. It was more fully described by him in the following year.[5]

---

[1] General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey, Minnesota, 1st Ann. Rep. for 1872, 1873, pp. 70-72.

[2] The Lower Silurian rocks. (Geology of central Wisconsin.) Geol. Wisconsin, survey of 1873–1879, vol. 2, 1877, p. 525.

[3] Ibid., 525.

[4] On the age of the Tonto sandstone. (Abstract.) Washington Phil. Soc. Bull., vol. 1, 1874, p. 109.

[5] Explorations and surveys west of the 100th Merid., vol. 3, 1875, p. 163; pp. 521–522.

HAMBURG.

The Hamburg limestone and the Hamburg shale are names used by Mr. Arnold Hague, in 1881, to designate the Upper Cambrian limestone and shale of the Cambrian section of the Eureka district, Nevada. The limestone is superjacent to the Secret Cañon shale and subjacent to the Hamburg shale. The latter is characterized by a well developed Upper Cambrian fauna.[1]

SECRET CAÑON.

This name was applied by Mr. Arnold Hague, in 1881, to a band of shale in the Cambrian section of the Eureka district, superjacent to the Prospect Mountain limestone and subjacent to the Hamburg limestone, characterized by a fauna that may be referred to the upper portion of the Middle Cambrian.[2]

KATEMCY.

Prof. Theodore B. Comstock, in describing the Upper Cambrian rocks of the central area of Texas, proposed the name "Katemcy" for the "Potsdam series," or Upper Cambrian.(?)[3] This terrane is named from the beds exposed in the valley of Katemcy Creek, Mason County.

RILEY.

This name was proposed by Prof. Theodore B. Comstock, for a series of sandstones which he considered to be superjacent to the Hickory series of the Central Texas, Cambrian section, and subjacent to the Katemcy or Potsdam series. He referred it provisionally to the Middle Cambrian zone.[4]

HICKORY.

This name was proposed by Prof. Theodore B. Comstock, for a series of strata that he considered to underlie the typical Potsdam Sandstone of the central Texas section. He referred the series provisionally to the Lower Cambrian.[5]

CONNASAUGA.

This name was proposed by Mr. C. Willard Hayes, for the Cambrian shales at the summit of the Cambrian section in northwestern Georgia. He correlated it with the Knox shale of Safford's Tennessee section, assigning to it a thickness of 1,600 to 2,000 feet.[6]

---

[1] Report (on work in Eureka District). U. S. Geol. Surv., 2d Ann. Rep., 1880-'81, 1881, p. 27; 3d Ann. Rep., 1883, p. 255.

[2] Ibid., pp. 27, 253.

[3] Comstock, T. B.: A preliminary report on the geology of the central mineral region of Texas. First Ann. Rept. Geol. Surv. Texas, 1889, p. 289.

[4] Ibid., p. 286.

[5] Ibid., p. 285.

[6] The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, vol. 2, Feb. 1891, p. 143, pl. 3.

This name seems to be a synonym of Montevallo shales proposed by Prof Eugene A. Smith.

MONTEVALLO.

The name Montevallo, or Choccolocco, shales was proposed by Prof. Eugene Smith, for a series of sandy shales of a great variety of colors, such as olive, green, brown, chocolate, yellowish, etc., that occur above the Coosa shales in northeastern Alabama.[1]

This name appears to be equivalent to Connasauga shales proposed by Mr. C. Willard Hayes.

CHOCCOLOCCO.

This is apparently a synonym of Montevallo.

COOSA.

The name Coosa shales was proposed by Prof. Eugene A. Smith for the shales in the Coosa Valley at the base of the Cambrian section. They are described as thin-bedded limestones with clay seams between.[2]

This name is also used by Mr. C. Willard Hayes in a paper read before the Geological Society of America, December 29, 1890, and published February 9, 1891. It was applied to the series of shales, some 3,000 feet in thickness, occurring at the base of the Cambrian section in northwestern Georgia.[3]

ROME SANDSTONE.

This name was proposed by Mr. C. Willard Hayes for a sandstone of Cambrian age occurring at Rome, Georgia. In connection with the Weisner quartzite it is given a thickness of from 2,000 to 3,500 feet. The correlation is with the Knox sandstones of Tennessee.[4]

BRETONIAN.

This name is applied by Mr. G. F. Matthew to the upper series of Cambrian rocks as found in the vicinity of St. John, New Brunswick, and on the island of Cape Breton, where the fauna of the division is well developed. It will be arranged as an Upper Cambrian formation.[5]

---

[1] Geological structure and description of the valley region adjacent to the Cahaba Coal Field. Geol. Surv. Alabama. Report on the Cahaba Coal Field, pt. II, 1890, p. 148. (Issued January, 1891.)

[2] Ibid., p. 148.

[3] The overthrust faults of the Southern Appalacians. Bull. Geol. Soc. America, vol. 2, Feb., 1891, p. 143, pl. 3.

[4] Ibid., p, 143.

[5] Illustrations of the fauna of the St. John group, No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1890, p. 129.

ACADIAN.

The name Acadian was proposed by Sir J. W. Dawson in 1867 for the series of rocks represented in New Brunswick by the St. John slate of Mr. G. F. Matthew.[1] In 1868 these observations were reprinted, with the statement that the discovery adds a new formation to the Paleozoic period in America. He says:

> This formation has as yet been known as the "St. John group," but I think this name unsuitable, both on account of the number of places known as St. John and on account of the variety of formations occurring near St. John, in New Brunswick, and would propose for the group now under consideration, characterized by *Paradoxides*, *Conocephalites*, etc., and the oldest known member of the Paleozoic of America, the name Acadian group, by which I hope it will be known to geologists in whatever part of America it may be recognized.[2]

In a recent paper on the fauna of the St. John group, Mr. G. F. Matthew limits the term Acadian to his Division 1 of the New Brunswick Cambrian section. This includes the fauna of the Paradoxides zone.[3]

ST. JOHN'S.

Prof. J. Beete Jukes in 1843[4] used the name St. John's slate for the slate as seen near St. John's, Newfoundland, beneath the Signal Hill sandstone. When referring, in 1862, to this work[5] he states he did not find any fossils in the lower slate formation, but that Mr. C. Bennett, subsequently found trilobites of the genus Paradoxides in the slates on the west side of St. Mary's Bay. These were named *P. bennetti* by Mr. J. W. Salter. On the map accompanying the report of 1843, the slates of St. John's extend southward from St. John's and around the southern point of the Avalon Peninsula to and about the Bay of St. Mary's.

The investigation of Dr. Alexander Murray and Mr. J. P. Howley in connection with the geological survey of Newfoundland, have shown that the slate carrying Paradoxides about St. Mary's Bay is a later formation than the slate at St. John's; and that the Paradoxides slates are unconformably superjacent to the slates to which Prof. Jukes gave the name of St. John's in 1843. This restricts the name as given by Prof. Jukes to the slate series of St. John's, described as from 2,000 to 3,000 feet thick. It was in this series of slates that the Rev. Moses Harvey discovered the fossil which Mr. Billings described as *Aspidella terranovica*. The entire series, along with the Signal Hill sandstone of Prof. Jukes, was referred to the intermediate or Huronian

---

[1] On recent geological discoveries in the Acadian provinces of British America. Proc. Am. Assoc. Adv. Sci., vol. 16, 1867, pp. 117-119.

[2] Acadian geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Islands. 2d ed., London, 1868. p. 638.

[3] Illustrations of the fauna of the St. John Group No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1891, p. 129.

[4] General report of the geological survey of Newfoundland in 1839 and 1840. London, 1843, p. 52.

[5] The Student's Manual of Geology. 2d edition, Edinburgh, 1862, p. 457.

system by Dr. Murray; and in the classification used in this memoir it is included under the Algonkian, as a pre-Cambrian formation.

In proposing a classification for the formations in the vicinity of St. John, New Brunswick, Mr. F. G. Matthew proposed the term, "St. John group" for several zones of soft black and dark gray, finely laminated shales alternating with zones of coarser grained slates, containing numerous thin beds of fine-grained sandstone.[1] The fossils were Lingula, a Conchifer, Annelids, and Coprolites. This was republished in 1865, and is used in all the latest publications by Mr. Matthew.

In view of the fact that the term "St. John's" was used for a distinct formation by Prof. Jukes in 1843, it appears best to continue to apply it to these slates of the Algonkian; and to use the later name "Acadian" for the slates at St. John, New Brunswick.

JOHANNIAN.

This name is proposed by Mr. G. F. Matthew for a local series of strata in the St. John basin of New Brunswick that occur between the Paradoxides zone, or Division No. 1, and the Upper Cambrian Zone, or Division No. 3, which he calls Bretonian.[2]

GEORGIA.

The name Georgia was incidentally used by Prof. Jules Marcou in 1860, when stating that "Prof. Emmons has always regarded the black slates of Georgia as a part of his Taconic system."[3] In the following year the name was used in volume 1 of the Geology of Vermont, in the systematic description of a group of formations, the typical one of which is a series of slates and shales above the "Red sandrock" in the town of Georgia, Vermont. There was also included in the group the roofing slate belt of Rutland County, Vermont, that passes into Washington County, New York. A provisional reference was made of a series of clay slates that occur in the central part of the State.[4] A full description of the formations referred to the group is given in the text, and their geographic distribution is delineated on an accompanying map.

Prof. Jules Marcou advanced the claim that he first used the name Georgia in October, 1860, which was followed in December, 1861, with a full definition of the group.[5] Prof. Hitchcock in reply to this, states

[1] Matthew, G. F.: Observations on the geology of St. John County, New Brunswick. Canadian Nat. vol. 8, 1863, p. 244.

[2] Illustrations of the fauna of the St. John Group No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1891, p. 129.

[3] On the Primordial Fauna and the Taconic System, by Joachim Barrande, with additional notes by Jules Marcou, Proc. Boston Soc. Nat. Hist., vol. 7, 1860, p. 375.

[4] Hitchcock, C. H. Geology of Vermont, vol. 1, p. 357.

[5] The Taconic of Georgia and the Report on the Geology of Vermont. Memoirs Boston Soc. Nat. Hist., vol. 4, 1888, pp. 123, 124.

that excerpts from volume 1 of the Geology of Vermont were distributed prior to December, 1861, and that it was in print by July, 1861.[1]

On a map, in the atlas accompanying the Geology of Canada for 1863, published in 1865, the Georgia group of Prof. Hitchcock is included with the "Red Sandrock" in a common color, and is so referred to in the legend. This includes the "Red Sandrock" series and the Georgia series of Prof. C. H. Hitchcock as one formation under the name of Potsdam.

In 1886 the "Red Sandrock" was included by Mr. C. D. Walcott with the shales of the Georgia series, in the Middle Cambrian or Georgia group.[2] The reference to the Middle Cambrian was changed to Lower Cambrian three years later.[3]

GRANULAR QUARTZ.

This is one of the first formations differentiated and named by Prof. Amos Eaton.[4] He referred it to the Primitive class and indicated its stratigraphic position on a section accompanying the index. The name was accepted by Dr. E. Emmons[5] in 1842 and placed as the second member of his Taconic system, between the second bed of Stockbridge limestone and the third bed of limestone. This section was corrected in 1844, so as to place the "Granular Quartz" at the base of the Taconic system.[6]

In 1887 the Olenellus fauna was discovered by Mr. C. D. Walcott in the "Granular Quartz" near Bennington, Vermont, thus determining its pre-Potsdam age.[7]

RED SANDROCK.

The occurrence of a red sandstone at Burlington Falls, Vermont, was mentioned by Prof. C. T. Jackson in 1844.[8]

In the scheme of Dr. C. B. Adams, illustrating the rocks of Vermont, as expressed in the nomenclature of the New York system, the Red Sandrock occurs above the Hudson River shales.[9]

The correlation thus indicated is that of the reddish brown Medina sandstone of the New York series with the reddish colored "sandstone" of Vermont, and the name Red Sandrock was applied to the latter, thus originating a term that has continued in geologic literature, not-

[1] Date of the publication of the report upon the Geology of Vermont. Boston Soc. Nat. Hist. Proc., vol. 24, 1888, p. 34.

[2] U. S. Geol. Survey, Bull. No. 30, 1886, p. 44.

[3] Stratigraphic position of the Olenellus Fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, p. 383.

[4] An index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, p. 21.

[5] Geol. of N. Y., Part 2, comprising the survey of the 2d Geol. (Northern) District, 1842, p. 144.

[6] The Taconic System; based on observations in New York, Massachusetts, Vermont and Rhode Island. Albany, 1844, p. 18.

[7] Discovery of fossils in the Lower Taconic of Emmons. Am. Assoc. Proc., vol. 36, 1888, p. 212.

[8] Final report on the Geology and Mineralogy of the State of New Hampshire, 1844, p. 161.

[9] First Ann. Rep. on the Geology of Vermont. Burlington, 1845, p. 61.

withstanding the fact that the rock itself is a magnesian limestone, with more or less siliceous and sandy beds alternating with the limestone.

In the second annual report of Vermont by Dr. Adams, in the description of a section of Snake Mountain, Addison County, the strata capping the mountains are designated by the name of Red Sandrock.[1]

PRIMAL.

The term Primal was proposed by the brothers Rogers in 1844 and defined as follows:

> Our Primal series embraces the four great rocks between the base of the Paleozoic strata and the base of the first limestone, the Calciferous sandstone of New York.[2]

The equivalent expression was Formation No. 1, and both terms have been used in the geologic work of Pennsylvania, Maryland, and Virginia, but they have not come into general use.

CHILHOWEE.

The name Chilhowee was proposed by Prof. J. M. Safford in 1856 for a series of sandstones and shales superjacent to the Ocoee conglomerates and shales and subjacent to the Magnesian limestone and Shale group, or what was subsequently called the Knox shale and the Knox limestone.[3]

By the discovery of the Olenellus fauna in the shale resting upon the quartzite of Chilhowee Mountain, the Chilhowee Mountain quartzite is referred to the Lower Cambrian and correlated with the Granular quartzite upon the western slope of the Green Mountains of Vermont.

WEISNER.

This name is proposed by Prof. Eugene A. Smith for the lenticular masses of quartzite that occur in the Montevallo shale of northeastern Alabama. He correlates the quartzite with the Chilhowee Mountain quartzite of Tennessee. This correlation is probably incorrect, as the latter quartzite is of Lower Cambrian age.[4]

This name is also used by Mr. C. Willard Hayes for a series of quartzites that occur between the Coosa shales and the Connasauga shales of the Cambrian section of northwestern Georgia. In connection with the Rome sandstone he mentions the correlation of it with the Knox sandstone, Potsdam or Chilhowee, Prof. Safford's Tennessee section, by Profs. Smith and Safford.[5]

---

[1] Second Ann. Rep. of Geol. Surv. of Vermont, 1846, p. 163.

[2] On American geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, p. 155.

[3] A geological reconnaissance of Tennessee; first biennial report. Nashville, 1856, p. 152.

[4] Geological structure and description of the valley region adjacent to the Cahaba Coal Field. Geol. Surv. Alabama. Rept. on the Cahaba Coal Field. Pt. II, 1890, p. 149.

[5] The overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, vol. 2, Feb., 1891, p. 142.

OCOEE.

This name was proposed by Prof. J. M. Safford in 1856 for a series of conglomerates and slates that he considered to be superjacent to the Mica-slate group and subjacent to the Chilhowee sandstone.[1]

PROSPECT.

For the lower members of the Cambrian section, in the Eureka district, Nevada, Mr. Arnold Hague proposed, in 1881, Prospect Mountain quartzite and Prospect Mountain limestone.[2] As now known the upper portion of the Prospect Mountain quartzite is characterized by the Olenèllus or Lower Cambrian fauna, and the Prospect Mountain limestone by the Middle Cambrian fauna of the Rocky Mountain section.

EASTERN AND WESTERN SANDSTONE.

These names were applied to the horizontal, evenly bedded sandstones of the south shore of Lake Superior, east and west of Keweenaw Point, by Dr. R. D. Irving in 1883 as convenient terms under which to describe the character of the sandstone and its geographic distribution.[3]

LAKE SUPERIOR SANDSTONE.

Dr. J. J. Bigsby described the red and white sandstone along the south shore of Lake Superior as early as 1825, and in the account of the geology of Lake Superior by Capt. H. W. Bayfield, he speaks of the sandstones of Lake Superior.[4] As used by Capt. Bayfield, the Lake Superior sandstone included both the Cambrian sandstones of the south shore, and the pre-Cambrian sandstones of Keweenaw Point and the north shore of the Lake. It has been used by various authors in the same general manner, and has little value as a term in stratigraphic geology.

POTSDAMIC.

Prof. C. H. Hitchcock proposed in 1888 for the rocks[5] containing the Cambrian fauna, the name Potsdamic or Taconic.

---

[1] A geological reconnaissance of Tennessee; first biennial report. Nashville, 1856, p. 151.

[2] U. S. Geol. Survey, Second Ann. Rep., 1880-'81, 1882, p. 27; 3d Ann. Rep., p. 254.

[3] The copper-bearing rocks of Lake Superior. U. S. Geol. Survey, Monograph, vol. 5; 1883, pp. 351, 365.

[4] Outlines of the Geology of Lake Superior. Quebec Lit. and Hist. Soc. Trans., vol. 1, 1829, pp. 15-22.

[5] Date of the publication of the report upon the Geology of Vermont. Boston Soc. Nat. Hist. Proc. vol. 24, 1888, p. 37.

CHAPTER IV.

SUMMARY OF THE PRESENT KNOWLEDGE OF THE FORMATIONS.

The data under this heading is assembled for each of the following Geologic Provinces:

Atlantic Coast Province.
Appalachian Province.
Rocky Mountain Province.
Interior Continental Province.

A brief résumé is given at the end of the description of the formations of each province and a general résumé of the Cambrian Group at the end of the chapter.

ATLANTIC COAST PROVINCE.

This includes the rocks referred to the Cambrian group on the Island of Newfoundland and the adjoining coast of Labrador, the provinces of Nova Scotia and New Brunswick, and Cape Breton, and the States of Maine, New Hampshire, and eastern Massachusetts.

NEWFOUNDLAND AND THE ADJOINING COAST OF LABRADOR.

The detailed knowledge we have of the Cambrian rocks of Newfoundland is obtained largely from the publications of the Geological Survey of Canada for the northwest and west coast and the Labrador coast, and from the descriptions by the Newfoundland Survey of the eastern and southeastern coast. To the latter there is added the results of a season's work on the Avalon peninsula, by the writer.

NORTHWESTERN NEWFOUNDLAND.

The Cambrian strata on the adjoining coast of Labrador are included with those of the Cambrian area of northwestern Newfoundland, as the two are considered to belong to one geologic province.

The section at L'Anse au Loup, on the north side of the straits of Belle Isle[1] shows 231 feet of arenaceous beds at the base, overlain by

[1]Logan, W. E.: Geological Survey of Canada; report of progress from its commencement to 1863. Montreal, 1863, p. 288.

143 feet of gray, reddish and greenish limestones. The section is, in detail, as follows:

	Feet.
1. Red and gray sandstones, sometimes of a reddish gray; consisting, in the lower part, of a conglomerate composed of rounded pebbles of white quartz from an eighth of an inch to 3 inches in diameter, in a matrix of fine-grained sandstone, made up of whitish and reddish quartz, and white and red feldspar. A similar fine-grained mixture constitutes the great mass of rock in the upper part. The beds vary in thickness from 3 inches to 3 feet, and many of them are penetrated vertically by *Scolithus linearis*, about a quarter of an inch in diameter, and always of a lighter color than the surrounding mass. Four feet below the summit there is a bed 3½ feet thick, of a mammillated or concretionary character; the concretions, which are from 1 to 10 feet in horizontal diameter, being composed of concentric layers from a quarter to half an inch thick	231
2. Gray, reddish, and greenish limestones, presenting on the strike great diversities of character. They sometimes consist of yellow-weathering, massive, nodular, argillaceous limestones, probably magnesian, holding lenticular patches of pure limestone, as well as of red and green shale from 3 to 6 feet in horizontal diameter. On the strike these yellow-weathering limestones pass in some parts into gray, compact, pure limestone, in thick, massive beds, while in others they are evenly divided into layers of only 2 or 3 inches thick. In Forteau Bay the whole mass appears to be more or less fossiliferous	143
	374

I examined the collections from these limestones now in the Canadian Geological Survey collections, and found the following species, most of which had been recognized and described by Mr. Billings:

Palæophycus incipiens.
Archæocyathus profundus.
Spirocyathes atlanticus.
Coscinocyathus billingsi.
Iphidea bella.
Kutorgina cingulata.
  labradorica.
Obolella chromatica.
Orthis 2 sp.
Stenotheca elongata.
  rugosa.
Hyolithes billingsi.
Salterella pulchella.
  rugosa.
Olenellus thompsoni?
Ptychoparia miser.
Protypus senectus.
Solenopleura (like S. nana).

In describing the extension of the rocks along the north shore of the Straits of Belle Isle, Sir William E. Logan states that they rest on the Laurentian gneiss, and extend along the coast for nearly 80 miles, with a probable breadth of 10 or 12 miles, and slope towards the water at an average of about 60 feet to the mile. In this stretch along the coast they are divided into five or six tabular masses, separted from one another by narrow denuded portions of the gneiss.[1]

On the Newfoundland shore sandstones occur that were referred to the Potsdam sandstone from their stratigraphic relations to superjacent limestones containing *Lingulepis acuminata*.[2] The data, however, does not fully sustain this reference. Following south along the west

[1] Op. cit., p. 287. [2] Op. cit., p. 289.

coast nearly 200 miles, to Bonne Bay, a more extended section of Cambrian strata is met with that is described in detail, as follows:[1]

Between 1 and 2 miles inland from the northeast side of the east arm of Bonne Bay there arises a range of hills of Laurentian gneiss, 2,000 or 3,000 feet in height, on the flank of which is exposed the following measured section:

A.

	Feet.
1. Blackish blue, fine-grained slate, with a cleavage independent of the bedding. Of this slate only 105 feet of the upper part are seen; the lower part is concealed in the space between the upper portion and the gneiss, and may comprise a thickness of about 230 feet	335
2. Blackish blue slate interstratified with gray quartzites, in beds of from 6 inches to 3 and 4 feet. In the 80 feet at the bottom the quartzites greatly predominate, and they constitute 15 feet at the top, while the intermediate 175 feet consist chiefly of slate	270
	605

B.

1. Light gray, yellow-weathering limestone, in beds of from 1 to 3 inches thick, interstratified with blackish-blue, slightly calcareous slate, both containing small specks of silver-white mica, which are more abundant in the limestone than in the slate. The limestones hold in abundance fragments of trilobites, chiefly belonging to three or four species. Among them is *Paradoxides (Olenellus) vermontana*, a new species of Bathyurus, and the pygidium of a species so closely resembling *B. extans* of the Birdseye and Black River formation, that it can scarcely be distinguished from it and may possibly be the same	80
2. Grayish green, micaceo-arenaceous shale, interstratified with a few beds of grayish quartzite weathering slightly yellow	80
3. Strata concealed	30
4. Reddish granular quartzite in thick beds, with numerous parallel joints in two directions, dividing the beds into rhomboids	105
5. Gray and grayish green, micaceo-arenaceous shale in beds from a quarter of an inch to an inch thick, interstratified with a few beds of gray, very ferruginous, sandy dolomite, and fewer of gray quartzite	127
6. Reddish quartzite, in beds of from 1 to 2 feet thick	34
7. Gray arenaceous dolomite, weathering yellowish brown, interstratified with reddish quartzite in beds of from 1 inch to 1 foot thick, and with reddish and grayish micaceo-arenaceous shale predominating toward the top. The beds of dolomite and shale contain fossils, among which are *Obolella chromatica?*, *Obolus labradoricus*, *Paradoxides vermontana*, *Conocephalites*, a new species of Bathyurus, and one or more undetermined species of Salterella.	27
	483

C.

1. Whitish quartzite in beds of from 6 inches to 2 feet, interstratified with light gray, micaceo-arenaceous shale, in layers of from 6 inches to 1 foot, which occur at intervals of from 5 to 10 feet	150

[1] Op. cit., pp. 865–867.

	Feet.
2. White and reddish quartzite, in beds of from 1 to 3 feet thick, interstratified toward the bottom with a gray arenaceous dolomite, weathering yellowish brown	160
3. White and reddish quartzite, in beds of from 1 to 3 feet thick, interstratified with greenish micaceo-arenaceous shale, constituting about one-half the amount	90
4. Gray, pure limestone, in beds of from 1 to 3 feet thick, marked with a few reticulating strings of yellowish-weathering dolomite. The rock is a mass of comminuted organic remains, among which are *Paradoxides vermontana*, and undetermined species of Bathyurus and Salterella, as before	20
5. Blackish blue, soft shale, interstratified with gray yellow-weathering limestone, probably magnesian, in beds of 1 or 2 inches thick. The quantities of shale and limestone are about equal, and the whole is intersected by reticulating strings of calc-spar	35
6. Gray, pure limestone, composed of comminuted organic remains, belonging to Paradoxides, Bathyurus, and Salterella, as before	27
7. Bluish black, soft shale, interstratified with gray yellow-weathering dolomitic bands, as before	60
8. Gray, pure limestone, probably composed of comminuted organic remains as before; underlaid by bluish black shale, inclosing nodules of blue compact limestone, some of which weather yellowish-brown, and are probably magnesian	13
9. Bluish black, soft shale of the same character as before, interstratified with a few beds of quartzite	68
	623
Total	1,711

I examined the species of Bathyurus referred to in No. 1 of Division B, and also some other fossils labeled as coming from Bonne Bay, and there can be no doubt that some mistake was made in labeling the specimens, for they certainly belong to the Trenton fauna and could not have been associated with the Lower Cambrian fauna of the section. All the Paradoxides referred to belong to the genus Olenellus or Mesonacis and several of the specimens of Bathyurus to the genus Protypus. If the section was correctly measured and the Cambrian fossils occur as mentioned all the strata belong to the Lower Cambrian, and the fauna is a part of the Georgian fauna of the Cambrian. From the accessible data I am not able to discover that the Upper Cambrian or Potsdam fauna has been found on the northwest coast of Newfoundland or on the Labrador shore.

SOUTHWESTERN NEWFOUNDLAND.

On the "Map showing the distribution of the Silurian and Carboniferous Formations (etc.) in St. George's and Port au Port Bays, Newfoundland," by Dr. Alexander Murray, 1873–'74, a considerable area is designated as Potsdam that is continued north into the valley of the Humber. The reason given for the identification of the Potsdam Terrane, in the Reports of the Geological Survey of Newfoundland for 1873–'74, '75, is that the strata placed within it are subjacent to the beds containing fossils of the Calciferous formation of the Lower Silurian.

This is not sufficient in the absence of Upper Cambrian fossils to establish the presence of the Potsdam horizon on the southwestern side of the island. It is quite probable that strata of Cambrian age occur, but as yet the proof of their presence is very defective.

EASTERN AND SOUTHEASTERN NEWFOUNDLAND.

The section at Canada Bay is as follows, according to Dr. Alexander Murray:[1]

	Feet.
A. Clouds Mountain bluish gray slates, conglomerates, and diorite	2,500
B. Salt Water Pond bluish gray, black, blue, reddish, and white limestones, yellowish gray and black slates, and gray and white sandstones, in some parts holding *Olenellus vermontanus*, Lingula, Scolithus and fucoids	2,000
C. Light and dark blue limestones and brown slates, with cherty limestone at the top	900
	5,400

The strata referred to the Cambrian system in southeastern Newfoundland are well exposed on the peninsula of Avalon and westward along the coast to the northern shore of Fortune Bay, and northward, on the western shores of Trinity Bay. Dr. Murray has given a general description of the terrane in the reports of the Geological Survey of Newfoundland for 1868 and 1870; and a fine geological map of the Peninsula of Avalon, by Dr. Murray and Mr. James P. Howley, 1881, shows the distribution of the Cambrian rocks. The correlated section is described as superjacent to pre-Cambrian "Huronian" rocks and as having a thickness of nearly 6,000 feet, of which 138 feet are limestone and the remaining portion argillaceous and arenaceous deposits.

The section in descending order is as follows:[2]

	Feet.
(*s*) Brown and black micaceous shales, with gray micaceous sandstones of Bell Island, Conception Bay. Organic contents are: two species of Lingula, four species of Palæophycus, *Eophyton linnæanum* (Torrell), and another Eophyton, *Cruziana semiplicata* (Salter) and some others	476
(*r*) Red and green sandstones and slates, with some calcareous beds at the base. Estimated thickness	1,426
(*q*) Kelly's Island sandstones and shales. A few fucoids were the only fossils observed in this division	720
(*p*) Black slate or shale. At Fortune Harbor this division was found to contain *Paradoxides bennettii*	150
(*o*) A bed of dark gray limestone. Fossils consist of broken fragments of trilobites and shells, among which latter a Lingula was observed	5
(*n*) Red, green, and black slates, or shales, which occasionally pass into a finely laminated argillaceous shale, as at Topsail Head. The fossils are *Paradoxides bennettii*, *Conocephalites gregarius*, and probably some other species not yet recognized	1,045

[1] Sequence and distribution of the rocks of the great Northern Peninsula. Geol. Survey Newfoundland, Report of progress for 1864. Revised edition, London, 1881, p. 15.

[2] Murray, Alexander: Of Primordial Silurian and Related formations. Rep. Geol. Surv. Newfoundland for 1870, St. John's, 1871, pp. 36–39. Geology of Newfoundland, 1881, London, pp. 237–239.

	Feet.
(*m*) Hard, thick beds of gray and sometimes reddish limestone. Two species of Conocephalites have been recognized by Mr. Billings, and a small fragment supposed of Paradoxides from a loose stone at Topsail Head; also Salterella and *Crania labradorica*. Thickness at Topsail Head.....	100
(*l*) Red, green, and blackish argillaceous slates. A few remains of trilobites were found at Random Island, one of which resembles *Bathyurus gregarius* (Billings)	250
(*k*) Conglomerate of Manuel's Brook, not recognized elsewhere	50
(*j*) Red and green argillaceous shales or slates. Thickness at Brigus South Head.....	150
(*i*) Red and flesh-colored limestones, in which some obscure fossils have been found, and an Archæocyathus detected by Mr. Billings.....	20
(*h*) Red slate	30
(*g*) Thin bed of impure red limestone	10
(*f*) Red slate.....	40
(*e*) Red, green, and gray sandstones, with occasional beds of conglomerate. The upper beds flaggy.....	750
(*d*) Green and reddish brown or purple slates, with smooth and regularly parallel cleavage, independent of the bedding, splitting into slabs under half an inch thick. This is the position of the workable slates of Smith's Sound and Random Island.....	137
(*c*) A bed of impure flesh-colored limestone	3
(*b*) Green slate, same character as *d*	10
	150
(*a*) Hard, dark green-gray sandstones with slaty divisions, the sandstone beds varying in thickness from 4 inches to 1 foot	600
Total.....	5,972

On page 160 of the reprint of the report of the Geological Survey of Newfoundland for 1868[1] a section is given of the strata of Great Bell Isle, as follows:

ASCENDING.

	Feet.
(1) Black or dark brown shales, with thin beds of sandstone from 2 to 6 inches thick, of a gray color on fracture, mica being thickly disseminated in both shales and sandstones, and especially at the division of the harder members	20
(2) Thin bands of sandstone like the preceding, weathering a rusty brown color, and divided by layers of black shale.....	6
(3) A hard, strong bed of gray sandstone, with conchoidal fracture, irregularly bedded, average thickness about	4
(4) Alternations of black shale and sandstone towards the top of the vertical cliff	60
(5) A heavy mass of strata, mostly sandstone, forms the crest of the cliff.....	10
(6) Alternations of very micaceous gray sandstone and shale, the former mostly thin-bedded, varying from 1 to 6 or 8 inches, with Cruziana in great profusion on many surfaces. Nodular concretions, holding Lingulæ among the shales	100
(7) The upper strata are a good deal concealed, but beds of sandstone occasionally crop out on the bed and banks of a small brook near the line of section, some of which is of a pale yellowish color, in some cases nearly a foot thick, estimated.....	196

[1] Murray, Alex.: Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868. St. John's, 1868. Revised edition, 1881.

	Feet.
(8) The upper stratum is also in great part concealed, but large, angular-jointed fragments of it are abundant on the surface all along the summit level, which are clearly in place, or only slightly removed. Some of these beds appear to be from 1 to 2 feet thick, are rather coarsely granular, of a grayish or greenish color on fracture, and contain crowds of organic remains, chiefly a species of Lingula. Estimated	80
Total	476

In No. 2 of this section I found, in 1888, a small species of Lingula (?), abundant remains of Cruziana, and an entire specimen of Olenus. Numerous trails of annelids occur on the surfaces of the sandstones, from one to six, inclusive.

Mr. E. Billings described the fossils obtained by the Newfoundland survey from Great Bell Island and named *Eophyton jukesi*, *Arthraria antiquata*, *Lingula murrayi*, *Lingulella ? affinis*, *L.? spissa*, and *Cruziana similis*.[1]

In the upper portion of No. 6 *Lingula murrayi* occurs in considerable abundance, and from No. 8 a large number of specimens of *Lingula spissa* were collected; *Eophyton linnæanum* Torrell and *Arthraria antiquata* occur in Nos. 2 and 4.

There is no detailed section given of the strata of Little Bell Island. The section, as determined by the writer in 1888, is made up of dark argillaceous and sandy shale, with beds of gray and dark sandstone, both thin-bedded and in massive layers. In the argillaceous shales *Lingula billingsiana* is very abundant and ranges through about 150 feet of strata. Toward the summit of the section on the west shore of the island a species of Hyolithes, and a long, slender shell, that may be provisionally referred to Lingulella, occurs in a light gray sandstone. A few feet below this horizon a new species of Lingula was found in a micaceous sandstone associated with the Lingula ? occurring below in the shales.

All the strata of Little Bell Island have a dip of about 7° westward toward Great Bell Island. If this dip be retained and the section be unbroken, the higher beds would pass beneath the strata on Great Bell Island, at a depth of about 1,200 feet. Dr. Murray in the generalized section mentioned, has given a thickness of 1,426 feet for the strata of Little Bell Island and that concealed beneath the waters of Conception Bay before reaching Great Bell Island.

A detailed section of the strata of Kelly's Island of what appears to be the same series as on Little Bell Island is published by Dr. Murray.[2] A small Lingula (*L. billingsonia*) was found midway of the 713 feet of strata. I found the same species to be very abundant in the shales of the lower portion of the Little Bell Island section.

[1] On some fossils from the Primordial rocks of Newfoundland. Canadian Naturalist, new ser., vol. 6, 1872, pp. 465-479.

[2] Of the sequence and distribution of the formations. Report upon the geological survey of Newfoundland for 1868. St. John's, 1868; revised edition, 1881, pp. 157-159.

The section on the mainland beneath Topsail Head, Conception Bay, was found to be as described by Dr. Murray.[1] The limestone at the base is separated from the "Huronian" rocks by a fault line. Over the limestone 100 feet or more of greenish shale completes the section. In the limestones were found:[2]

Obolella atlantica.
Kutorgina labradorica.
Scenella reticulata.
Hyolithellus micans.
H. micans var. rugosa.
Hyolithes princeps.
impar.
Microdiscus speciosus.
Microdiscus, sp. undet.
Olenellus (H.) bröggeri.
Avalonia manuelensis.
Solenopleura bombifrons.
Agraulos (S.) strenuus.
Agraulos (S.) sp. ?

In the superjacent green shales a few fragments of a trilobite were observed that indicated by a portion of the glabella and eye-lobe a large species of Paradoxides. The evidence here obtained of the relation of the Olenellus and Paradoxides faunas being somewhat inconclusive, the section at Brigus Head, on the west side of Conception Bay, was next examined and found to be essentially the same as that at Topsail Head, with the addition of a greater thickness of green and red shales above the limestone, and a sandy deposit beneath the limestone which rested unconformably against the "Huronian." The limestone series is divided into three bands. In the lowest, a specimen of *Hyolithes impar* was found, similar to that in the limestone at Topsail Head, associated with fragments of *Olenellus* (*H.*) *bröggeri*, *Microdiscus helena* and *Ptychoparia?* sp. (?). In the second bed of limestone, fragments of trilobites were seen; and in the upper bed *Olenellus* (*H.*) *bröggeri* and *Agraulos strenuus* were observed, the latter in great abundance. No fossils were discovered in the superjacent slates.

The stratigraphic succession on Manuel's Brook, as measured by me in August, 1888, is as follows:[3]

MANUEL'S BROOK SECTION.

	Feet.
(1) Coarse conglomerate, in massive layers. The material next to the gneiss varies in size from bowlders of quartz and gneiss 6 feet in diameter down to small pebbles, and in the upper beds from pebbles to fine sand. Strike N. 80° E. (Magnetic); dip 12° to 13° N.	35
(2) Irregular beds of calcareous sandstone, siliceous limestone, and greenish-colored argillaceous shale, covering the irregular upper surface of the conglomerate ..... Fossils: *Obolella atlantica, Hyolithellus micans, Helenia bella, Hyolithes princeps, H. impar, H. quadricostatus, H. similis, H. terranovicus, Scenella reticulata, Stenotheca rugosa*, varieties *acuta-costa, erecta, laris* and *pauper, Platyceras primævum, Microdiscus helena, M. speciosus, Olenellus* (*H.*) *bröggeri, Avalonia manuelensis, Agraulos* (*S.*) *strenuus* and var. *nasutus, Solenopleura bombifrons, S. harveyi* and *S. howleyi.*	0 to 25

[1] Op. cit., p. 154.

[2] Walcott, C. D: Stratigraphic position of the Olenellus fauna in North America and Europe. Am. Jour. Sci., 3d ser., vol. 37, 1889, p. 378.

[3] Op. cit., pp. 380, 381.

	Feet.
(3) Greenish argillaceous shale, conformably subjacent to 2	40
(4) Reddish-colored argillaceous shale	4
(5) Calcareous sandstone, with pinkish limestone in irregular masses	2
(6) Green argillaceous shale with thin layers of hard, dark, ferruginous sandstone, interbedded at several horizons	270

Strike N. 80° E.; dip 12° N.

Fossils: Near the base the head of an Olenellus was found; also fragments of an Agraulos or Ptychoparia. At 218 feet from the base a layer of pinkish limestone contained the head of an Agraulos, like *A. strenuus*, and many fragments of trilobites. Fifty-two feet higher up quite an abundant fauna was found, and the following species were collected: *Lingulella* sp. *a.*, *Acrothele matthewi*, *Agnostus* sp. *a.*, *Agnostus* sp. *d.*, *Paradoxides hicksi*, *Conocoryphe matthewi*, and *Liostracus* sp. *a.*

(7) Dark argillaceous shales with thin layers of limestone and sandstone at various horizons	295

Fossils: Zone A: From 10 to 20 feet from the base the following species were collected: *Lingulella* sp. *a*, *Linnarssonia misera*, *Acrothele matthewi*, *Hyolithes* sp. *a*, *Agnostus* 3 sp. *a*, *b*, *c*, *Microdiscus punctatus*, *Paradoxides hicksi*, *Conocoryphe* (*C.*) *matthewi*, *C. elegans*, *Agraulos socialis*, and *Liostracus tener*.

Zone B: Forty-five feet higher the fauna is much larger and includes: *Linnarssonia misera*, *Lingulella* sp. *a*, *Orthis* sp. ?, *Stenotheca* sp. ?, *Agnostus punctuosus*, *Agnostus* 5 sp. *b*, *c*, *f*, *g*, *h*, *Microdiscus punctatus*, *Paradoxides davidis*, *P. hicksi*, *Paradoxides*, sp., *Anopolenus venustus*, *Conocoryphe elegans*, *Ctenocephalus matthewi*, *Erinnys venulosa*, *Ptychoparia robbi*, *P. variolaris*, *Holocephalina inflata* and *Agraulos socialis*.

From 235 to 250 feet from the base a belt occurs in which a small species of Aristozoa occurs in large numbers, associated with *Lingulella* sp. *a*, *Agnostus* sp. ?, and the heads of a small *Ptychoparia?* sp. undet.

(8) Alternating bands of dark shale and dark, compact sandstone that carry a small species of Orthis in large numbers	400

The section is here cut off by the shore of Conception Bay.

The fauna of No. 2 is essentially the same as that of the limestones of the Topsail Head and Brigus sections, and proved conclusively that the Olenellus fauna is subjacent to the Paradoxides fauna.

Beneath the conglomerate beds of Manuel's Brook and between them and the subjacent Archean gneiss, there is, according to Messrs. Murray and Howley, a series of red and green sandstones, conglomerates and massive sandstone strata, which, according to their tabulated section, have a thickness of 1,800 feet. They are exposed on the north side of Trinity Bay and partially on St. Mary's Bay. I think we should have more data before deciding that this series of 1,800 feet is really subjacent to the Manuel's Brook conglomerate; although it is extremely probable that such is the case, judging from the character of the Trinity Bay and Conception Bay sections.

On the islands in the bay the Upper Cambrian horizon is well developed. In the lower arenaceous shales at Lance Cove, on Great Bell Island, were found *Eophyton* sp. ?, *Cruziana semiplicata*, *Arthraria antiquata*, *Olenus* sp. undet., and at a higher horizon, near the center of the island, *Lingulepis affinis* and *Lingula ? murrayi*, with fragments of Cru-

ziana. In the sandstone at the summit of Little Bell Island, 20 feet above a band of sandstone carrying *Lingula ? billingsiana* and an elongate, narrow species of Lingulella, a long slender Hyolithes ? and a broad species of Hyolithes occur. In the dark argillaceous shales beneath *L. ? billingsiana* occurs in great numbers.

The conglomerate (No. 1 of the section) was traced, just north of the outcrop of the gneiss, a mile to the west of Manuel's Brook, and the shales and limestone of No. 2 were seen in a number of sections, resting directly upon it. On the brook the stratigraphic succession is unbroken up to the summit of No. 8, and the strata are conformable and undisturbed with the exception of the dip of 12° to the north.

The Manuel's Brook section is the only one known to me on the North American continent where the typical Olenellus and Paradoxides faunas occur in an unbroken stratigraphic section. The Olenellus fauna is well developed and typical, and the same is true of the Paradoxides fauna.

As shown on the Avalon Peninsula the early Cambrian Sea transgressed across all the pre-Cambrian rocks, including the Aspidella slates and Signal Hill sandstone and the great series of altered slates and sandstones and, subjacent to them, the Laurentian gneisses. This unconformity is of a similar type to that between the Algonkian formations of the Lake Superior and Adirondack regions and the Upper Cambrian sandstone. In each, three groups of rocks have been deposited and subsequently elevated by an orographic movement and eroded before the deposition of the Cambrian sediments. The relations of the Cambrian and pre-Cambrian rocks are all well shown upon the geological map of the peninsula of Avalon, Newfoundland, 1881, prepared by Mr. James P. Howley.

NOVA SCOTIA.

It is very probable that the Cambrian group is represented in the gold-bearing slates of the Nova Scotia section, but as yet the only means of correlation is the supposed stratigraphic position. The principal details and arguments for including this series in the Cambrian have already been given under the historical review. (Ante, pp. 56–59.) It may be that they represent in large part a pre-Cambrian, Algonkian group equivalent to the St. John slates of Newfoundland.

NEW BRUNSWICK AND CAPE BRETON.

Our present knowledge of the Cambrian geology of the area under consideration is obtained from the reports of the Geological Survey of Canada, and the numerous papers on the geology and paleontology of southern New Brunswick by Mr. G. F. Matthew.

In the report of the Geological Survey of Canada for 1870–'71, a detailed description is given of the geographic distribution of the St. John group (pp. 134–143); and other details are added in the report for 1878–'79 (pp. 6D–8D). From these reports and the map accompany-

ing the latter, Mr. G. F. Matthew has compiled a summary of the information relating to the St. John terrane. He says:[1]

The strata of the St. John group fill a number of narrow, trough-like basins, lying between the Bay of Fundy and the central carboniferous area of New Brunswick. Of these basins, that on which the city of St. John is situated is the most important, and it is here also that the life of the period can be studied to the best advantage. The St. John basin lies diagonally across the ridges of Huronian rock that are found in the eastern part of St. John County and touches the ridge of Laurentian rocks that divides this county from King's. As might naturally be expected, the coarser sediments found at the base of the St. John group are largely derived from those older rocks, chiefly the Huronian; and the line of division between it (the St. John group) and the Huronian formation is marked by conglomerates of mechanical origin which show no trace of the hardening process by which the Huronian conglomerates and breccias have been so firmly cemented.

The Conglomerates of the St. John group are most fully developed in the eastern part of the St. John Basin, under the lee of the high ranges of Huronian hills which exist in that direction. In Portland and the city of St. John, at the western end of the basin, the following section represents the succession of members in this group in ascending order:

	Feet.
Division 0:	
(*a*) Red Conglomerate—wanting at that part of the basin where this section was made	
(*b*) Red and green sandy slates	150
Division 1:	
(*a*) Coarse gray sandstone or quartzite	50
(*b*) Coarse gray sandy slate (Linguloid shells)	50
(*c*) Fine gray and dark gray slaty shales (Trilobites, etc.)	25
(*d*) Fine black carbonaceous slaty shales (Trilobites, etc.)	75
Division 2:	
(*a*) Dark gray slates with thin seams of gray sandstone	220
(*b*) Coarse gray slates and gray flagstones	200
(*c*) Gray sandstones and coarse slates (Linguloid shells)	130
Division 3:	
(*a*) Dark gray finely laminated slates	450
(*b*) Black carbonaceous and dark gray slates, less fissile than the last	300
Division 4:	
Slates and flags, resembling 2*a* and 2*b* (Linguloid shells)	800
Division 5:	
Black carbonaceous slate like, 3*b* (Orthids, Trilobites, etc.)	450
	2,900

Beyond Division 5 the beds are supposed to be repeated by an overturn, and have a width across nearly vertical measures of 3,000 feet. Owing to this folding of the measures there is some uncertainty as to where the summit of the formation is, and the section given may not include the whole series of deposits. The faunæ of Divisions 2 and 5 are very imperfectly known, but there are much larger species of Linguloid shells in these divisions than in Division 1, and the orthids of Division 5 are different from *Orthis billingsi* of Division 1.

The Conglomerate at the base of the St. John group marks the time when the sea of the Acadian epoch invaded the valleys of the Huronian formation near St. John. No trace of life has yet been found in these coarse sediments, nor in the red and green

[1] Illustrations of the fauna of the St. John group. Royal Soc. Canada, Proc. and Trans., vol. 1, section 4, 1883, pp. 87–108. Supplementary section, pp. 271–279.

slates into which they pass. After the colored mud of which these slates are composed was deposited, an abrupt change took place in the character of the deposit, and white sands were evenly spread over the whole basin. It is in the upper part of these sands that one meets with the earliest traces of primordial life. These first forms are linguloid shells of several genera. Such shells become more abundant in the upper part of the white and gray sandy beds, and were evidently littoral species, as on tracing the sandstones westward for half a mile they are found to change into a gray slaty and pebbly deposit—evidently an old beach line—and finally disappear.

Probably the physical condition of the St. John Basin at this early period was unfavorable to the growth of the trilobites; but the land was sinking, and an additional depth of water in this sheltered area soon encouraged the growth and multiplication of the crustacean fauna. As the sediment which settled from the sea water in this deepening bay became finer, the remains of marine animals were preserved in greater numbers and variety, so that in the layers of fine slate in Group *c* of Division 1, many genera chacteristic of the early Cambrian age are found.

In Group *d* the slaty mass becomes quite fine and dark colored, but near St. John is much affected by slaty cleavage, and the fossils are so much distorted, especially in the upper part, as to be unrecognizable.

In the beds of Division 2, a return of littoral conditions, and the influx of sand, interfered with the prosperity of the crustacean fauna, and as in the lower sand beds of Division 1, linguloid shells become the prevailing fossils. The Paradoxides which I will describe in this article are those of the intermediate mud beds, now converted into a mass of slaty rock (Division 1, *c*).[1]

On the evidence of the contained fauna, Mr. Matthew correlated the fauna of the Paradoxides zone of the St. John group with that of the Solva group of Wales, as defined by Dr. Hicks.[2]

In addition to the section as found at St. John there is to be added a series described by Mr. Matthew, occurring below Division 1, on Hanford Brook, in the eastern part of St. John County. In the report upon the geology of southern New Brunswick, by L. W. Bailey, in 1865, this mass of sediments was spoken of as the upper member of the Coldbrook group and distinct from the St. John group; it was subsequently joined to the St. John group by Messrs. Bailey and Matthew in a report of progress of the geological survey of Canada, 1870–'71, p. 59, because the want of conformity existing between the two formations could not then be established; but it is now found that this series is unconformable not only to the St. John group, but also, as had been previously discovered, to the underlying Coldbrook group.[3] The section is as follows:[4]

	Thickness in feet.
1 (*a*) Coarse purplish red Conglomerate, resting on an amygdaloidal greenstone (toadstone) of the Coldbrook group	60
(*b*) Gray and purplish flags and sandstones with worm-casts, seaweeds (Palæochorda and Buthotrephis), and numerous spicules of sponges	70
(*c*) Purplish red sandstones, with greenish layers. Remains of seaweeds (Phycoidella), animal tracks (Psammichnites and Helminthites), worm-burrows (Arenicolites) etc	240

[1] Op. cit., pp. 87–89.

[2] The geologic age of the Acadian fauna. The Primitive Conocoryphean. British Assoc. Rep., 54th meeting, 1884, pp. 742–744.

[3] On a basal series of Cambrian rocks in Acadia. Canadian Record Science, vol. 3, 1888, p. 22.

[4] On Cambrian Organisms in Acadia. Royal Soc. Canada, Trans., vol. 7, Proc., sec. 4, 1890, p. 138.

	Thickness in feet.
2 (*a*) Purplish red Conglomerate, more friable than 1 *a*	35
(*b*) Soft purplish red shales, with green glauconite grains, the upper part firmer and more sandy, greenish gray layers interspersed especially towards the base. Platysolenites, Obolus, Volborthella, etc	175
(*c*) Purplish sandy shales, with a few bands of greenish shale. Worm-casts (Scolites)	300
Measures concealed, probably of this series	320
	1,200

In this series of 1,000 or more feet of beds, the very oldest layers which are fine enough to preserve organic markings, have trails and casts of marine worms, and also contain seaweeds, one a Palæochorda or allied genus, the other a weed with a flat frond similar to Buthotrephis. That these beds are marine is clearly shown by the great numbers of spicules of hexactinellid sponges which they contain.

About 350 feet above the base, where the measures are flaggy, tracks of annelids are again abundant. Besides the smaller trails and burrows, there are frequent tracks of a marine animal, possibly a worm, similar to the markings on the Fucoidal sandstone of Sweden, which, by Prof. O. Torrell, have been referred to the genus Psammichnites. A very similar track, with corresponding casts, occurs on the surfaces of the purple streaked sandstones (Assise 3) of Band *b* in Division 1, of the St. John group, and a similar trail occurs as high up as the lower band of Division 2 of that group. Above this point, such markings have not been found, though the kind of rock—flags and slates—is favorable to their occurrence. The flags of the middle of Division 2, of the St. John group, seem to be the horizon of *Cruziana semiplicata* (Salter) and *C. similis* (Billings); but I have not found them here.

About 100 feet or more above the horizon where Psammichnites appears, separated from it by a Conglomerate, indications of the Olenellus fauna show themselves. These consist of Volborthella (a chambered cell resembling an Orthoceras), the cystidean genus Platysolenites, Pander, and a large Obolus, allied to *Michwitzia* (formerly *Obolus?* or *Lingula?*) *monilifera*, Linrs., of the Eophyton sandstone of Sweden and the upper part of the "Blue Clay" of Russia. Some of the layers in this part of the series abound in soft green grains similar to the glauconite grains of the Cambrian rocks in Russia. The paste enveloping them is red.

A number of beds between this point and the top of the Basal series contain worm-casts and burrows, and some have remains of small strap-like seaweeds.

In summing up the facts bearing on the comparative age of this part of the Cambrian rocks in Acadia we get no aid from the typical genera of this horizon, Olenellus and Mesonacis, but the Acadian rocks contain other genera of this fauna which serve to fix their age with a certain degree of accuracy. Some of these genera, however, are such as may have a wider range of existence in time than the trilobites, and therefore are not of the same homotaxial value. The trilobites that do occur are not so definitive as some others.[1]

In his latest table of classification Mr. Matthew arranges the Cambrian System as it occurs in Acadia as follows:[2]

	Localities.
D.—Upper Cambrian (Potsdam series)	Unknown.
C.—Middle and Lower Cambrian, Acadian series	St. John, etc.
B.—Lower Cambrian, Georgian series	C. Breton.
A.—Basal Cambrian, Etcheminian series	St. John, etc.

[1] Op. cit., p. 143.

[2] On the classification of the Cambrian rocks in Acadia. No. 2. Canadian Record of Science, vol. 3,

In describing in 1888 (at that time called series B) the Paradoxides zone, or C of the preceding tabulation, the term "stage" replaces the word "division" as heretofore used by Mr. Matthew, and the divisions of the series are given as follows:[1]

Stage 1.—This includes the lower part of the series as high up as Paradoxides are found. The divisions of this stage are as follows:—

Band (assise) *a*. Hard gray sandstone or quartzite. Fossils, none known.

Band (or assise) *b*. Dark-gray sandstones and gray sandy shales. Fossils: Ellipsocephalus, Agraulos, Hipponicharion, Beyrichona, etc.

Band (or assise) *c*. Gray shales. Fossils: Paradoxides, Conocoryphe, Liostracus, Microdiscus, Agnostus, etc.

Band (or assise) *d*. Dark gray shales. Fossils: Paradoxides, Ptychoparia, Solenopleura, Microdiscus, Agnostus, etc., of different species from those in assise *c*.

Stage 2.—This consists of gray flags and sandy shales. The subdivisions have not been worked out, but the stage corresponds to the lower half of the Olenus zone in Europe. No species of the genus Olenus have been found in it.

Stage 3.—Dark-gray and black shales. Fossils: Ctenopyge, Kutorgina, Orthis, etc. This corresponds to the upper half of the Olenus zone of Europe. The shales in Cape Breton, which contain Peltura and Sphæropthalmus, belong here. There are in the St. John Basin gray flags, which overlie the Ctenopyge beds, but no higher stage than the Olenus zone has been established by fossils.[2]

In a series of sections of Cambrian rocks in Acadia,[3] the upper Cambrian or Olenus beds are shown to be present in St. John County in the Portland section.

Just as this report is going to press (May 1, 1891) I received the fifth contribution of Mr. G. F. Matthew upon the fauna of the St. John Group. In the introduction he gives a description of the structure of the St. John basin and sections of the measures at St. John. He finds that all three of his divisions of the Cambrian are present. Division 1 he names Acadian, Division 2 Johannian, and Division 3 Bretonian.[4]

The Cambrian rocks of Cape Breton Island are described with many details by Mr. Hugh Fletcher in 1877 and 1878, but the various outcrops do not appear to have been well correlated. The section in McLean Brook, on Little Bras d'Or Lake, is as follows:[5]

	Feet.
(1) *Carboniferous conglomerate* and related rocks.....	
(2) Feldspathic sandstone and impure limestone, of white, green, amber, red, and other colors, mixed, and in distinct beds of different thickness; sometimes associated with greenish, soft, soapy rocks, probably decomposed felsites; films of hematite in the joints.....	254

[1] On the classification of the Cambrian rocks of Acadia. Canadian Rec. Sci., vol. 3, 1888, p. 73.

[2] Mr. Matthew writes me under date of October 25, 1890, that he has found the Arenig graptolitic fauna in the St. John series, thus establishing the presence of the Lower Silurian (Ordovician) fauna above the Olenus zone.

[3] Matthew, G. F. On the classification of the Cambrian rocks in Acadia. No. 2. Canadian Rec. Sci., vol. 3, 1889, p. 308.

[4] Illustrations of the fauna of the St. John Group, No. 5. Royal Soc. of Canada, Trans., vol. 8, 1891, p. 129.

[5] Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Sur. Canad. Rept. Prog. for 1876–'77. Montreal, 1878, p. 431.

	Feet.
(3) Blackish and gray slate, fine sandstone, and argillaceous limestone; also, compact, feldspathic rock, mixed with limestone of different colors. Not well seen	84
(4) Dark and pale gray slates, with thin layers of quartz, spotted with iron pyrites and mined for gold	66
(5) Greenish gray, fine-grained, pyritous rock, resembling sandstone and yielding easily to the knife	19
(6) Black and gray argillite, full of small twisted layers of quartz, which are sometimes so numerous as to constitute an impure quartzite, spotted with pyrites. Associated with and overlie dark-blue, plumbaginous argillite, also full of pyritous quartz layers	65
(7) Bluish-gray, pearly, papery slates, cleft in every direction and traversed in the bedding and across it by streaks of calcspar and quartz	30
(8) Bluish felsite, crystalline limestone and quartz, confusedly mixed in contorted beds	37
(9) Bluish-gray coherent argillite	60
(10) Greenish, decomposed, feldspathic rock, of uncertain thickness	110
(11) *Red syenite* in steeply rising hills	
	725

The Cambrian rocks occur as long narrow areas resting on the subjacent Laurentian rocks, as shown on the map accompanying Mr. Fletcher's report of 1876–'77; and on the map accompanying the report for 1875–'76. In the text of the latter report the rocks are described as they occur on St. Andrew's Channel, and the geographic distribution is given on the map. From a small outcrop on the Mira River a collection of trilobites was obtained that indicate the upper Cambrian fauna. They include, as identified by Mr. Matthew, *Peltura scarabeoides*, *Sphærophthalmus alatus*, and *Agnostus pisiformis*.[1] It is not certain that all the rocks referred to the Lower Silurian by Mr. Fletcher belong to the Cambrian group, but as far as known all the fossils that have been found indicate the upper Cambrian series.

MAINE.

The presence of typical rocks of the Cambrian group in the State of Maine is not yet proved. It is quite probable, as in the case of Nova Scotia, that the series of slates referred to the Cambrian actually belong at that horizon. But until paleontologic evidence is obtained, the question will be an open one. The stratigraphic position of the slates and their lithologic character enable us to speak of them tentatively as belonging to the Cambrian group. That they were deposited in the same basin as the Cambrian series of New Brunswick and Massachusetts is not probable.

NEW HAMPSHIRE.

All the references of strata to the Cambrian group in New Hampshire are of a provisional character. They are based upon more or less im-

[1] On the Cambrian faunas of Cape Breton and Newfoundland. Royal Soc. Canada, Proc. and Trans. vol. 4, sec. 4, 1887, p. 147.

perfectly determined stratigraphic horizons and the fact that there is a thick mass of sediments, usually without fossils and largely argillaceous in character, that appear to be pre-Silurian in age. By their lithologic character they are correlated with formations referred to the Cambrian group, as found in Maine and Nova Scotia, that have similar lithologic characters and occur in a similar stratigraphic position. All these doubtful formations are in turn correlated by their lithologic characters and supposed stratigraphic position with the Cambrian beds of Newfoundland and New Brunswick.

In speaking of the Mica-schist series of New Hampshire, Prof. C. H. Hitchcock says[1] that there unquestionably exists an enormous thickness of mica-schists in southern New Hampshire above the Huronian series. "No author who has devoted any attention to these groups has suggested an inferior position for them. They may be called Silurian, Cambrian, or pre-Cambrian, according as each author is inclined to regard New England, very ancient, or on the verge of the Paleozoic."

It is doubtful if these exposures should be referred to the Atlantic Coast Province. It is done at present as a matter of convenience.

EASTERN MASSACHUSETTS.

The description of the Cambrian rocks of the Boston Basin, by Prof. W. O. Crosby, is the most recent and the most thorough of any we have, and the summary of our present knowledge of them is taken mainly from his paper. He says:[2]

> The oldest rocks which we have found are the Primordial slates and quartzites, and the age of these is certainly and definitely known only at the Paradoxides quarry, in Braintree. We appear to be justified, however, in regarding them, provisionally at least as all of about the same age, partly on account of a general lithologic resemblance, but mainly because their relations to the different classes of eruptive rocks are everywhere the same. In Weymouth and Braintree, where we first met these rocks, they are either typical clay slates or slightly calcareous; but along the northern base of the Blue Hills occasional layers are distinctly siliceous. They probably underlie a large part of the Boston Basin, being covered by the conglomerate and the newer slate; and north of the basin, as shown in the ninth lecture, they occur in isolated areas among the eruptive rocks. In some of these areas, especially in the Middlesex Fells and Melrose, and in Woburn, clay slate similar to that in Quincy and Braintree is repeatedly interstratified with quartzite, while toward the southwest, in Natick, and also in Reading and Lynnfield, there are extensive developments of quartzite with little or no slate. It is very clear that the quartzite north and west of the Boston Basin is the source of the quartzite pebbles which play such a prominent part in the composition of the conglomerate, especially in the central and northwestern sections of the basin. In general, the quartzite is more and the slate less abundant northwestward, indicating that the ancient shore line along which these strata were deposited lay in that direction, and originally the Primordial strata were probably spread continuously over all the region to the southeast of that line.

[1] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist. Bull., vol. 1, 1884, p. 168.

[2] Physical History of the Boston Basin. Lowell free lectures, 1889–1890. Boston, 1889, pp. 19, 20.

The deposition of the Primordial strata was followed by a period of disturbance of this part of the earth's crust, during which they were strongly compressed, being thrown into sharp folds having, in general, a northeast and southwest direction. This appears, also, to have been a period of intense volcanic activity. The quartzite and slate were shattered and isolated by great volumes of basic lava, which we now call diorite; and, as indicated by the compact and scoriaceous diorite of the Middlesex Fells and other localities, immense floods of lava were also poured out on the surface, concealing the sedimentary rocks. In breaking through the quartzite and slate, the diorite has often followed the planes of stratification in those rocks, and thus appears in many cases to be regularly interstratified with them; and this bedded appearance of the diorite is greatly increased by the very perfect flow-structure which was developed in large masses of it, as well as by the distinctly schistose or foliated structure sometimes resulting from the subsequent action of both mechanical and chemical forces. We are thus able to explain the fact that the diorite has been frequently mistaken for a stratified or sedimentary rock.

The eruption of the diorite was probably followed by a prolonged period of quiet erosion, which was finally terminated by the advent of a second period of intense and long continued igneous action, during which only acid rocks—the granites and felsites—were formed. All over this region the granite has broken through the Primordial strata and the diorite in the most irregular and intimate manner.

Prof. Crosby considers that after the deposition of the argillites and the eruption of the rocks occurring as dikes the series was raised above the sea level and subjected to long-continued erosion, prior to a downward movement or subsidence. As the surface passed slowly below the level of the sea a thick bed of conglomerate was spread over the earlier series of rocks and a fine silt or clay carried out into the deep water of the ocean. At the same time eruptive rocks were repeatedly poured out over the sea floor, where the beds of gravel and sand were accumulating, thus forming alternating beds of conglomerate and sandstone with beds of melaphyr and porphyrite. [1]

Of the subsequent depositions of sediment, he says:

Alternations of the conglomerate with beds of both sandstone and slate are also of common occurrence, indicating oscillations of level during this period. But the downward movement prevailed, until finally the water became too deep and quiet and too remote from the shore, in this vicinity, to permit the formation of conglomerate and sandstone; but these coarse sediments were gradually replaced by slate during the dying out of the volcanic activity. These tranquil, deep-sea conditions must have continued for a very long time, for the argillaceous sediments accumulate very slowly and yet the slate series has a thickness of from 500 feet to fully 1,000 feet or more. The slates are probably somewhat thicker than the conglomerates, and were doubtless several if not many times longer in forming. Of the life existing in the sea at this time we unfortunately know but little, as the slate is very generally destitute of fossils; and the full chronologic significance of the few organic remains that have been obtained from the layers of limestone in the slate at Nahant is still undetermined. [2]

There is evidently an error in Prof. Crosby's interpretation of the stratigraphic succession of the formations he describes, as the fauna at Nahant is of an older date than that found in the argillites at Braintree. If, however, the conglomerates, with their contemporaneous eruptive

[1] Op. cit., p. 20. [2] Op. cit., p. 21.

rocks, belong to the same series as the East Point slate and limestone the entire series must be referred to the Cambrian.[1]

In his report of 1880 Prof. Crosby considers that the strata of the Boston Basin were deposited in a depression excavated in the crystalline formations and that there are several formations belonging to the Cambrian. First, a conglomerate, represented by the Roxbury puddingstone. Second, a slate series which incloses the Paradoxides zone in South Braintree. He assigns to the conglomerate a maximum volume not exceeding 1,000 feet, and considers that the greatest thickness of the slate can not be much less than that of the conglomerate, although in some cases certainly falling below 500 feet.[2] At the trilobite quarry in Braintree, the known locality of Primordial fossils, the slate is described as of a greenish gray color, "somewhat siliceous, fine-grained, and remarkably uniform. Minute grains of pyrite are pretty generally diffused. In the quarry the rock is apparently only very coarsely jointed; but the weathered surface reveals much finer division by this means. The stratification is very massive and can hardly be detected, except by means of the trilobite remains; these may be supposed to lie in the plane of the bedding, and according to this indication the strike is E.–W., and the dip S. 80°–85°. Across the strike, southerly, the slate, still apparently maintaining a high dip in that direction, is met at a distance of perhaps 300 feet by fine-grained grayish and reddish Huronian granite, while on the west the same granite cuts off the slate at about twice the above distance from the trilobite quarry; that is, the contact of the two formations, as shown on the map, is oblique to the strike of the slate."[3] On the map the slate series throughout the Boston Basin is correlated with the slates at Braintree, and represented by a common color.

---

[1] In a letter received from Prof. Crosby, dated January 27, 1891, he says: "The Nahant slate is entirely isolated, and concerning its relations to the conglomerate we *know* nothing. I have supposed, however, that it should be referred to the newer series, above the conglomerate." Of the general geology of the Boston Basin he says:

"Assuming that the slates of the Boston Basin now *known* to be Cambrian are overlain in succession by the conglomerates and a newer slate series (my present working hypothesis), it is still possible, I suppose, that all these rocks, in the Boston Basin, may be Cambrian; notwithstanding the marked uniformity between the conglomerate and lower slates.

"The weak points in the stratigraphy are (1) the general (not entire) absence of slate pebbles in the conglomerate; (2) the absence of clear sections showing the conglomerate resting upon a lower slate series. Wherever the base of the conglomerate is seen, it reposes *upon* the *granite* or *felsite*. Some of the sections are *very clear* and unmistakable in this respect; and apparently the same granite and felsite are eruptive through the Braintree slates. It would, of course, be difficult to *prove* that the granites and felsites are all of the same age; but it seems best to assume that until the contrary clearly appears.

"The best general statement of the stratigraphy of this region appears therefore to be this: A lower slate, known to be Cambrian; cut in succession by diorite, granite and felsite; all these rocks overlain *unconformably* by the conglomerate of unknown age; and the conglomerate in turn overlain conformably by a newer slate of unknown age.

"The chief problems are, then, to determine which are older and which are newer slates, and to determine the age of the conglomerate and upper slate.

"As an indication of progress, we have the discovery by Mr. Woodworth, just reported, of fossils in the slate of both Somerville and Newton."

[2] Contributions to the geology of Eastern Massachusetts. Boston Soc. Nat. Hist. Occasional papers, No. 3, 1880, p. 266.

[3] Op. cit., p. 192.

According to Dr. M. E. Wadsworth[1] the strata at the trilobite quarry dip a little west of south at an angle of 55°. This is nearly as given by Mr. Isaac Lea in 1858.[2] It is quite probable that the variation in angle of dip mentioned by different observers is owing to the position of the exposures in the quarry, at the time of their respective visits, and by their mistaking the cleavage for the plane of bedding.

Dr. Crosby[3] describes the rocks at East Point, Nahant, as composed of a very dark gray, almost black, compact slate, with a strike N. 60° E.; and nearly uniform northerly dip of about 40°. The slate is inclosed in, and extensively cut by, the coarsely crystalline pyroxenic rock of the Naugus Head series. The slate, except where it is vesicular, is of a uniform grayish black color and holds thin beds of limestone aggregating, perhaps, 20 feet of calcareous matter. The character of the limestone and its mode of occurrence are precisely like those of Mill Cove, in Weymouth, 13 miles distant. The limestones are interstratified with the slate and not always distinguishable from it. The color is light gray and its texture varies from compact to finely crystalline or saccharoidal. Thin seams and veins of siliceous material become evident on the weathered surface.

In the interbedded limestones Mr. A. F. Foerste discovered in 1889 traces of a species of Hyolithes which he identified as specifically the same as a species found in the decomposed limestones of North Attleborough[4] He proposed the name *Hyolithes inæquilateralis*, but I think it is identical with *Hyolithes communis*, var. *emmonsi*, of the Lower Cambrian horizon at Troy, New York. He states that the Nahant limestones are the equivalent of the red slates in North Weymouth; and that it is very probable the red slates and included limestones are stratigraphically beneath the Braintree Paradoxides beds. Also that the red slates of Mill Cove, in North Weymouth, are of Olenellus age and beneath the Paradoxides strata.

The district embracing the Cambrian rocks of Bristol County, Massachusetts, is well described by Prof. N. S. Shaler. He says:

> Several geologists have observed the fact that between Providence, Rhode Island, and Wrentham, Massachusetts, we have an extensive development of interbedded conglomerates, shaly slates, and sandstones, the whole separated from the other detrital deposits of this region by peculiarities of color. * * * Various conjectures have been made as to the age of these deposits. They have been thought by one observer to resemble the Trias, while others, owing partly to their position, have assigned them to the Devonian age.[5]

Prof. Shaler discovered fossils of the Lower Cambrian or Olenellus zone in this series of rocks in 1883, which for the first time gave data

[1] On the relation of the Quincy granite to the primordial argillite of Braintree, Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 21, 1883, pp. 274–277.

[2] [On the trilobite formation at Braintree, Massachusetts]. Phil. Acad. Sci. Proc., vol. 9, 1858, p. 205.

[3] Contributions to the geology of Eastern Massachusetts. Boston Soc. Nat. Hist. Occasional papers, No. 3, 1880, pp. 195, 261, 262.

[4] The Paleontological horizon of the limestone at Nahant, Massachusetts. Boston Soc. Nat. Hist. Proc., vol. 24, 1889, pp. 261–263.

[5] On the geology of the Cambrian district of Bristol County, Massachusetts. Bull. Mus. Comp. Zool., Harv. Col., vol. 16, 1888, pp. 13, 14.

for determining the geologic age of the deposit. On the east the Coal Measures of the Narragansett Basin occur. On the west side he considers the rocks to be of pre-Cambrian age, as they consist mainly of gneissoid rocks of various composition, and a great area of dark greenish chloritic deposits which appear in part at least to be metamorphosed conglomorates and shales. Owing to the large amount of drift material covering the country, no absolute contact with the pre-Cambrian rocks was observed, nor is the overlap of the Carboniferous upon the Cambrian shown in any section.

Of the rocks he says:

> The Cambrian rocks exhibit very little sign of metamorphic action. The shales indicate a slight amount of infiltration, and in the conglomerates the pebbles all retain essentially their original character, save that they are sometimes slightly indented one into the other. The cement of the mass is not more altered than is usual with our unchanged conglomerates. Its general characters, save for its reddish color, is undistinguishable from the deposits of Millstone grit age in the neighboring coal fields.[1]
>
> So far fossils have been found in rocks of this section which probably do not in the aggregate include more than 100 feet or so of the total section of the Cambrian series. However, as these deposits are of the same aspect, as all the red slates and conglomerates of the area, it appears at present reasonable to include all rocks of this description with the above-mentioned series. The total thickness of the section which I have termed Cambrian is not accurately determinable. It probably amounts to not far from 2,000 feet. In the main it consists of thin bedded shaly layers which occasionally pass into moderately thick, fine grained, greenish and reddish slates. Intermingled with these in several levels we have a number of layers of conglomerate, perhaps as many as half a dozen distinct beds, varying in thickness from 200 to 300 feet. In all cases these conglomerates are frequently interrupted by thin layers of shale or sandstone. * * * The rocks from which the pebbles were taken are mainly identifiable in the western portion of the field before described.[2]
>
> The sediments composing this Cambrian section appear to have been derived from rocks substantially the same as those which now lie in the field west of the area. Although fossils have been found in a small part of the section, close study makes it plain that by far the greater portion of the strata are clearly azoic. The frequent return of conglomerate layers and the coarseness of the pebbles show that during most of the time when the beds were accumulating the region was near shore; so, too, the large amount of sandy matter even in the slates affords a presumption that the region was not remote from the coast line. About 100 feet of shale beds have been subjected to a very careful search for organic remains. The total thickness of the deposits in which any trace of life has been found probably does not exceed 100 feet, and even in this section only a small part of the rocks actually contain fossils.[3]

Prof. Shaler suggests that the conglomerates were accumulated during an ice epoch; and he presents several arguments for this view. He states that the relations of the beds carrying the fauna at North Attleborough with those of the Paradoxides zone of Braintree are not discoverable by comparison with the Massachusetts Bay and Narragansett deposits. At the time he wrote the stratigraphic relation of the Olenellus fauna as found at North Attleborough with the Paradoxides fauna was not known, except that the Scandinavian geologists state

[1] Op. cit., pp. 16, 17. [2] Op. cit., p. 18. [3] Op. cit., p. 20.

that in their country, the Paradoxides zone occupied a superior position to the Olenellus zone. With the knowledge we now have of the stratigraphic succession of the Cambrian faunas, the Paradoxides beds of Braintree are considered to be superior to the Lower Cambrian rocks of Attleborough.

RÉSUMÉ.

The physical characters and condition of the rocks constituting the formations referred to the Cambrian in this province indicate that they were accumulated not far from the shore line, and that several fluctuations in the level of the sea bed occurred during Cambrian time. On the coast of Labrador the accumulation of sand was followed by a deepening of the sea and the deposition of calcareous mud. That the depth was not profound, is shown by the character of the limestone and its fauna, and the presence of lenticular masses of red and green shale. The 231 feet of sandstone, and 140 feet of limestone in the section represent only a portion of the Lower Cambrian or Olenellus zone. Two hundred miles to the south, on the west coast of Newfoundland the presence of 605 feet of slate beneath the alternating series of limestone and quartzite, over 1,000 feet in thickness, tell the same story of relatively shallow water accumulation.

On the Atlantic coast side, at Canada Bay, there are 2,500 feet of slate, conglomerate and eruptive rock, subjacent to a series of limestones and slates nearly 3,000 feet in thickness. There is here a greater development of limestone than anywhere to the south along the Atlantic coast line. It appears to have accumulated upon the bed of a protected sea not far distant from the shore and to have been frequently interrupted in deposition by the throwing down of a considerable thickness of argillaceous mud.

In southeastern Newfoundland the assembled sections have, according to Messrs. Murray and Howley, a thickness of nearly 6,000 feet, of which 128 feet are limestone, and the remaining portion argillaceous and arenaceous deposits. In the section on Manuel's Brook a conglomerate rests upon the pre-Cambrian gneiss, and upon the upper bed an irregular, arenaceous limestone in which layers of more or less pure limestone occur. This limestone-forming epoch was of very short duration, and was succeeded by an accumulation of clay that now forms a series of shales nearly 1,000 feet in thickness before sandy layers appear. When once the sandstones begin to alternate with the shales, they continue on up to the summit of the group and are very abundant in the Upper Cambrian. The sediments of southeastern Newfoundland were accumulated in bays of the pre-Cambrian sea and derived almost entirely from the adjacent shore, either as sand and silt, worn from the rocks by the sea, or brought down to it by tributary streams.

The 4,000 feet or more of rocks in the New Brunswick section are almost entirely shales with a few sandstones and basal conglomerates.

It is the record of the accumulation of sediments in a gradually deepening sea.

The eastern Massachusetts section is largely formed of shale, except in the lower part, where a small proportion of limestone occurs in the Olenellus zone, much as in the southeastern Newfoundland section.

The great thickness of shales referred to the Cambrian in Nova Scotia, Maine, and New Hampshire probably represents much more than the Cambrian group, or it may be entirely a pre-Cambrian formation or a post-Cambrian formation. It is only *probable* that they are of Cambrian age. They may represent deep-water accumulations in which no organic remains were buried.

As a whole, we may regard the Atlantic Coast Province, during Cambrian time, as including bays and the adjacent shores of the Algonkian land, in and along which sediments, mostly of an argillaceous and arenaceous character, accumulated. The relative level of the sea bed varied, but in the main the depression greatly exceeded the elevation. The depth of water in which the sediments forming the limestones and shales accumulated was probably considerable, but not a deep sea in the present sense of the term. A few hundred or a thousand feet on a gradually sinking sea bed (in relation to the coast line) would give the required conditions. From the character of the sediments and the faunas it is probable that land barriers existed to the eastward of the present coast, and that none of the deposits were accumulated off the shore facing the open ocean.

As left by erosion the Lower Cambrian now occurs on the Labrador coast, on the western and eastern sides of Newfoundland, in New Brunswick, and eastern Massachusetts. The Middle Cambrian has been recognized on the eastern coast of Newfoundland, in New Brunswick, and eastern Massachusetts. The Upper Cambrian is known in southeastern Newfoundland, Cape Breton Island, New Brunswick and doubtfully on the southwestern coast of Newfoundland. (See Pl. II.)

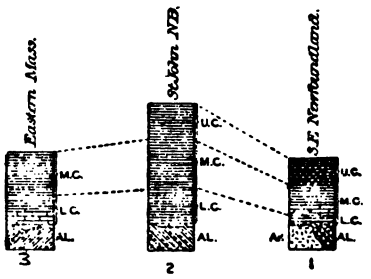


FIG. 1. Typical sections of the Atlantic Coast Province. Vertical scale, 6,400 feet to the inch.

APPALACHIAN PROVINCE.

The Appalachian Province includes the outcrops of Cambrian strata on the line of the Appalachian System of Mountains, from the Gulf of St. Lawrence on the north to Georgia and Alabama on the south.

For convenience in presenting geologic data the Appalachian Province is divided into:

A.—Northern Appalachian District.
B.—Southern Appalachian District.

NORTHERN APPALACHIAN DISTRICT.

The Northern Appalachian District includes the Hudson River and Lake Champlain area, east of the river and lake, and an extension northeastward into Canada as far as the vicinity of Cape Rosier on the Gulf of St. Lawrence.

The geographic distribution of the Cambrian strata of the Northern Appalachian District, south of the Canadian extension, is delineated on a geologic map of eastern New York and western Vermont published in 1888 by Mr. C. D. Walcott.[1] On this map the "Granular Quartz," "Red sandrock," "Georgia slate," and Potsdam sandstone are differentiated as far as the known data would permit. The stratigraphic relations of the various divisions in Vermont are shown in a series of sections by Prof. C. H. Hitchcock,[2] and for New York by a section on the above-mentioned map.

The "Granular Quartz" is found on the western side of the Archean rocks, from southeastern New York and western Connecticut northward to Massachusetts, and into Vermont nearly to the Canadian border. The exposed outcrop is more or less interrupted because of the removal of the rock by erosion or its concealment by superjacent deposits.

In Vermont the "Granular Quartz" is a very compact, hard rock that passes into a number of varieties. It is described in the Geology of Vermont[3] as granular, gray, or reddish quartz rock; fine granular or arenaceous quartz rock: granular porous quartz, or pseudo-buhrstone; quartzose aggregate; quartzose breccia; quartzose and micaceous conglomerate. There are also associated with it talcose and mica schists and limestone. The quartzite is remarkably compact and enduring, and it occurs in bowlders all over the southern part of Vermont, in Massachusetts, New York, and Connecticut, many miles from the parent ledges. Along the range of the rocks the bowlders cover the surface, and in some instances this is the only way in which the line of outcrop of the formation is indicated. Details of the geographic distribution in Vermont are given in volume 1 of the Geological Survey. A section of 973 feet was measured in East Dorset by Prof. C. H. Hitchcock, and the thickness of the formation in Vermont is estimated at 1,000 feet. It retains its essential characters in passing southward into Massachusetts, New York, and Connecticut.

On the western summit of Clarksburg Mountain, northeast of Williamstown, the basal bed of the quartz series is a conglomerate, resting unconformably upon pre-Cambrian gneiss. The conglomerate is succeeded by beds of quartzite, usually compact, hard, fine grained, and

[1] The Taconic system of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 229–242, 307–327, 394–401.

[2] Geological sections across Vermont and New Hampshire, Am. Mus. Nat. Hist. Bull., vol. 1, 1884, pp. 155–179, pl. xvi, xvii.

[3] Hitchcock, C. H. Hypozoic and Palæozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 342.

of a light gray color, in layers varying from a few inches to 2 or 3 feet and even up to 6 feet in thickness, on the spurs to the north of Clarksburgh Mountain. In the town of Bennington, a few miles further north, the writer measured a section of the quartzite 400 feet in thickness. It is formed largely of light gray, nearly white, compact, fine grained, and massive bedded quartzite, with alternating beds of hyaline quartz. At this locality fossils other than the Scolithus borings, which were known to occur at a number of localities in Vermont, were found in 1887 for the first time in situ in the quartzite. The species belong to the genera Nothozoe, Hyolithes, and Olenellus. Traces of a trilobite, apparently of the genus Olenellus, were also found 100 feet above the gneiss on the western summit of Clarksburg Mountain. In the bowlders on the line of the outcrop of quartz, to the north of Bennington, traces of fossils have long been known, among which are *Nothozoe vermontana*, *Hyolithes communis*, and *Olenellus thompsoni*.

Prof. J. D. Dana describes the quartzite in its extension into western Massachusetts, western Connecticut, and eastern New York. It varies very little from the characteristic features shown at the north, and from its disturbed condition no sections were obtained of its entire thickness. At Stissing Mountain, in Dutchess County, New York, it rests upon the Archean, and is a massive bedded, compact quartzite, in which the genus Olenellus and *Camerella minor* have been found. It here passes above into a limestone in which *Hyolithellus micans*, a characteristic Lower Cambrian species, occurs.[1]

In a paper read before the Geological Society of America at its second annual meeting, December 30, 1890, Dr. J. E. Wolff gave an account of the discovery, by Mr. A. F. Foerste and himself, of fossils of Lower Cambrian age in the limestones of the East Rutland Valley. The limestones rest conformably upon the quartzite which carries Olenellus in Bennington County. Dr. Wolff identified the species as *Kutorgina* sp.? and Salterella.[2] The evidence of the Lower Cambrian age of the limestones is not fully proved, as the two genera may range up into the Middle Cambrian.

He mentioned that in the West Rutland Valley, and in the valley between the West Rutland and East Rutland Valleys, the limestones contain fossils of Calciferous Chazy-Trenton age, or those which will be found above the Cambrian horizon. From his section it is probable that the Middle and Upper Cambrian faunas will be found to range up into the limestones beneath the Calciferous horizon, as has been discovered by Prof. W. B. Dwight in Dutchess County, New York, and Prof. Frank Nason, in Sussex County, New Jersey.

As a whole, the "Granular Quartz" may be said to consist of a shore deposit accumulated along the western shore of the Green Mountains

[1] The Taconic system of Emmons and the use of the name Taconic in Geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 236.

[2] Bull. Geol. Soc. Am., vol. 2, 1891, pp. 334, 335.

during early Cambrian times; the sediments vary from pure quartz sand to mixtures of sand and argillaceous and calcareous mud.

The "Red Sandrock" series is confined almost entirely to northern Vermont, not appearing south of Addison County. In the northern part of Addison County it comes into contact with and merges into the "Granular Quartz" series. It has not been recognized in contact with the Archean rocks of the Green Mountains. From this, and its having less of the character of a shore deposit and from its occurring west of the line of outcrop of the "Granular Quartz," it is quite probable it is a deeper water accumulation, though contemporaneous with the "Granular Quartz." The Georgia slates, in the town of Georgia and in northern Vermont, are conformably superjacent to the "Red Sandrock." As the formation is traced to the south, the "Red Sandrock" series disappears, and the Georgia slates and shales, with their interbedded limestones and sandstones, represent the entire Cambrian section; so it is very probable that the Georgia series as found in southern Vermont and eastern New York represents or is equivalent to the "Granular Quartz" and the "Red Sandrock." The "Granular Quartz" has been described separately, but it is more convenient to unite the "Red Sandrock" and the Georgia slates, because the sections usually show the latter resting conformably upon the "Red Sandrock" series throughout northern Vermont. The geographic distribution of the Canadian extension of the "Red Sandrock" and the Georgia slates is shown on a map by Sir Wm. E. Logan, entitled "The distribution of the rocks belonging to the Potsdam, Quebec, and Trenton groups of the east side of Lake Champlain," accompanying an Atlas of maps and sections of the Report of Progress of the Geological Survey of Canada for 1863, published in 1865. The formations extend north of the boundary line about 5 miles, where they appear to have been cut out by faults that bring the superjacent formations into contact with them.

The "Red Sandrock" series consists of white and red dolomites and sandy layers. Some of the strata are mottled red and white, and a few are brick red or Indian red. Some beds contain a considerable amount of siliceous sand, and all weather a yellowish or reddish brown. They are also interbedded with gray argillaceous limestones and buff sandy dolomites weathering brown. This description is taken from Logan's notes on the formation near the Canadian boundary. To the south, in the town of Georgia, Franklin County, Vermont, they form a bluish gray dolomitic limestone, followed by a steel-gray dolomitic limestone that passes into a mottled limestone or the Winooski marble. This in turn is subjacent to gray dolomitic limestones in massive layers, some of which are mottled reddish and white, though the larger part are gray and yellow. Still higher up the reddish pink dolomitic limestones appear. There are many variations in the color and composition of this series between the Canadian border and its point of disappearance 40 miles to the south.

The Georgia slate series, according to Prof. C. H. Hitchcock, consist in Vermont of several varieties of rock.[1] They are (1) clay slate; (2) roofing slate; (3) clay slate approximating to micaceous sandstone; (4) various kinds of limestone; (5) brecciated limestone; (6) conglomerate formed of pebbles of limestone.

A carefully measured section extending up through the "Red Sandrock" and Georgia series, beginning at the base of the western face of the cliff overlooking the level that reaches to the shore of Lake Champlain, in the town of Georgia, Franklin County, Vermont, and extending southeastward to Parker's quarry, a little south of the Georgia post-office, gives the following:[2]

	Feet
(1) Massive bedded, bluish gray dolomitic limestone, with many inosculating threads and bunches of a yellowish-drab sandy limestone that weathers in relief[3]	35
(2) No. 1 passes into a steel-gray dolomitic limestone that weathers to a dark buff and bluish black, with angular fragments of bluish gray limestone appearing irregularly at the surface. At 160 feet from the base the first band of mottled limestone, "Calico" or Winooski marble, is met with. The latter grades into a reddish dolomite, free from mottling, and then in a gray limestone. (Fossils, Hyolithellus ?)	200
(3) Gray dolomitic limestone in massive layers, some of which are mottled, reddish and white, but the larger part are gray and yellow. Many of the gray layers break up into a columnar structure, the columns being at right angles to the bedding. In a reddish-colored limestone, 200 feet from the base, a slender elongate tube occurs, probably *Hyolithellus micans*	475
(4) Reddish pink, dolomitic limestone, weathering to a reddish brown and decomposing on the exposed edges to an arenaceous, dark, brownish-red rock that shows numerous fragments of fossils: *Kutorgina labradorica*, *Obolella* (?) sp., *Salterella pulchella* (?), *Ptychoparia adamsi*, *Olenellus thompsoni*	100
(5) Gray arenaceous limestone in rough, massive layers, passing into more evenly bedded, light gray, arenaceous limestone. Fossils similar to those in 4 occur in the lower portion	190
Total thickness of limestone	1,000
(6) Georgia shales.—Argillaceo-micaceous and arenaceous shales, containing numerous fossils, at Parker's ledge, and showing deposition contact on No. 5	200

Strike at Parker's Quarry, N. 30° E., dip 8° to 12° E.

The fossiliferous shales at Parker's Quarry contain: *Palæophycus incipiens*, *P. congregatus*, *Diplograptus simplex* [now, 1891, *Phyllograptus* (?) *cambrensis*], *Climacograptus* (?) *emmonsi*, *Kutorgina cingulata*, *Orthisina orientalis*, *O. festinata*, *O. transversa*, *O. sp.* (?), *Microdiscus parkeri*, *Mesonacis vermontana*, *Olenellus thompsoni*, *Olenoides marcoui*, *Bathynotus holopyga*, *Ptychoparia adamsi*, *P. vulcanus*, *Protypus hitchcocki*, *P. senectus*, and *P. senectus* var. *parrulus*.

[1] Hypozoic and Paleozoic rocks. Report on the geology of Vermont, vol. 1, 1861, p. 358.

[2] Walcott, C. D. Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, pp. 15, 17.

[3] A mile south of the line of the section about 75 feet of arenaceous limestone occurs beneath this bed. Fifty feet from the base I found during the summer of 1890 *Obolella crassa* ?, *Salterella* sp.? *Hyolithes* 2 sp., and fragments of a species of Olenellus. A few feet higher in the section the heads of Protypus sp. ? and of Olenellus sp. ? were found. Traces of the Olenellus fauna were also found at points 85, 153, and 193 feet above the lowest horizon.

Feet.

(7) East of the Parker quarry the rocks are argillaceous shales, with occasional layers of hard gray limestone one-half of an inch to 2 inches thick, that carry numerous fragments of a linguloid shell 3,500

Strike of shales near top of 7, N. 40° to 60° E., dip 60° SE.

(8) Light gray quartzite 50

(9) Gray limestone in massive layers, with occasional intercalated bands of hard argillaceous shale similar to that beneath the limestone. Many of the beds of limestone appear to have been broken up into fragments and recemented in situ 1,700

Average strike of limestone beds N. 50° E., dip 50° to 90°; average dip 60° SE.

In this limestone belt, 1 mile north of where the section crossed, a few fossils were found; *Lingula*, n. sp., *Orthisina* undt. (fragment), *Camerella* undt. (probably new), *Agnostus* like *A. orion*, and *Ptychoparia* like *P. adamsi*.

(10) Argillaceous shales, very similar to those in the Parker ledge, continue on up to the opposite side of the line of the Vermont Central Railroad track. At the base the shales rest conformably against the limestone of 9, and above appear to be cut off by a fault.

Strike N. 50° E., dip 60° to 80° SE., for a distance beyond the limestone; the dip then decreases and does not exceed 20° for a long distance, until within 1,000 feet of the railroad track, where the shales become coarser and changed by addition of arenaceous material, and the dip increases.

Total thickness to fault line of No. 10, 3,500 to 4,500 feet.

No. 8 of the section when traced on its strike to the southwest increases in force very rapidly to the thickness of 500 feet or more, and also changes from a quartzite to a more or less calcareous sandstone, containing irregular fragments of argillaceous shale. Followed to the northeast, it soon disappears and the limestones rest directly on the shales. Continuing northeast on the limestone (9), it is found to decrease rapidly, and a mile northeast of where it is over 1,500 feet in thickness the width across the outcrop is not over 150 feet, and soon the shales above it and those below it come together, the limestone having disappeared. Southwest of the line of the section the width of the outcrop narrows, and north of Georgia Plains post-office the entire section is covered by beds of sand.

No. 9 appears to be a great lenticular mass of limestone (lentile of Marcou) with intercalated beds of argillaceous shale, and more rarely with arenaceous beds imbedded in the argillaceous shales. The fauna is Cambrian in character, and, in the absence of Olenellus and other typical Middle [now Lower] Cambrian fossils approaches that of the Upper Cambrian or Potsdam sandstone.

A section taken east of Highgate Springs beginning on the east side of the same fault as the Georgia section, gives a slightly greater thickness, and more arenaceous matter in the limestone series beneath the Georgia shales. The limestones are here 1,170 feet in thickness and the Georgia shales 1,000 feet, above which there is apparently a conformable series of calcareous sandstones, with a thickness of 850 feet, to where they are cut off by a fault line. A section measured east of the village of Swanton, does not show as great a thickness of the limestone beneath the Georgia shale, and a fault line cuts obliquely across the shale. On the east side of the fault 200 or 300 feet of shales occur, and many layers of conglomerate limestone, the fragments of limestone varying in size from small pebbles to masses 6 feet in diameter. The

fossils in the limestone conglomerate have an Upper Cambrian aspect, and include *Lingula sp. ?*, *Agnostus sp.?*, *Amphion sp.?*, *Bathyurus sp. ?* Below the horizon of the conglomerate and in situ in the shales, there were found the genera Lingulella, Agnostus, Ptychoparia and Solenopleura. With the exception of the Solenopleura the species appear to be identical with those of the limestone lentile (9) of the Georgia section. A section measured east of Swanton by Sir William E. Logan gave but 520 feet of the limestone (Red Sandrock) series.[1] But farther to the north, nearly on the line of the Canadian boundary, he found 1,410 feet of limestone in the section, proving that this portion of Cambrian terrane thickens rapidly to the north.

The section measured in the town of Georgia is the most complete yet taken in Vermont (ante., pp. 278, 279). At the base a great belt of dolomitic limestone 1,000 feet in thickness rests against, and, by an overthrust fault, overlaps the Trenton limestone of the Lower Silurian (Ordovician). What was originally beneath the Cambrian limestone is yet undetermined. In the Highgate section the limestone belt is nearly 1,200 feet thick. The base is unknown, and it does not appear, so far as I know, in the section between the boundary of the United States and Canada and the outcrop in the town of Georgia. I have suggested that the great mass of shaly argillite east of the Vermont Central Railway track in the Georgia section may be older than the limestone at the base of the section, but until further evidence is obtained this is merely conjectural.[2]

During the field season of 1890 I studied the "Red Sandrock" series of the Georgia section, and found a little to the south and at the base of the original section that there was a band of buff-colored calcareous sandstone some 50 feet in thickness. In the upper beds of this, Obolella, like *Obolella crassa*, *Hyolithes americanus*, *H. communis*, *H.* sp. undt., *Hyolithellus micans*, and fragments of Olenellus occur. In a lead-colored magnesian limestone, passing into a buff-colored limestone 15 feet above the sandstone, fragments of Olenellus and the head of Ptychoparia, apparently identical with *P. trilineata*, were found, and in the superjacent pinkish magnesian limestone with interbedded drab-colored limestone, at horizons of 85 feet, 113 feet, and 198 feet above the sandstone, fragments of fossils that I recognized as portions of Olenellus and very perfect specimens of Salterella sp.? occur in the decomposed silicious limestones.

The discovery of the Olenellus fauna in the lower portion of this magnesian limestone series gives the fauna a range through 1,000 feet of limestone and the 250 feet of superjacent Georgia shale.

The fragments and heads of the genus Olenellus that were found in the lower beds were not sufficient to determine whether it was the equivalent of the *Olenellus asaphoides* of the Washington County section or not.

[1] Geological Survey of Canada: Report of progress from its commencement to 1863. Montreal, 1863, p. 281.

[2] Walcott, C. D.: Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, 1886, p. 19.

It is quite probable that it is, from the character of the associated fossils. As the vertical distribution of the fauna in the Olenellus zone will be treated of in a future paper, further reference will not be made to it at present.

The shales and slates superjacent to the Olenellus-bearing beds of the Georgia slate, at Parker's quarry, do not apparently belong to the Lower Cambrian, but are the representative of the middle portion of the Cambrian section. This view was advanced by Prof. Jules Marcou, in 1885,[1] except that he placed the same series of shales which occurs at St. Albans beneath the Georgia slates or Olenellus zone. The stratigraphy was erroneous, but the suggestion that the St. Albans slates correspond to the Paradoxides belt of the Atlantic Coast area will probably be found to be correct. In such an event Professor Marcou's name St. Albans will be a useful addition to the nomenclature of the Cambrian group in northern Vermont. It will, however, be difficult to differentiate between the St. Albans group and the superjacent beds carrying the Upper Cambrian fauna.

In the group of sections taken across New Hampshire and Vermont by Prof. C. H. Hitchcock[2] the Georgia series is called Potsdam and Cambrian; and in section XI, on Pl. 17, the Georgia shales (Cambrian of section) are represented as resting conformably on the magnesian limestone (Potsdam of section) in the town of Milton. This is the same as in the Georgia section a few miles to the north. The great mass of argillites, east of the railroad track in the Georgia section, are placed under the term Cambrian by Prof. Hitchcock, and the reference may possibly be correct; but as yet there have not been any recognized Cambrian fossils obtained in it, either at this point or to the north or south.

In southern Vermont the Georgia slate series widens out, and includes the great roofing-slate belt that extends through Rutland County and into Washington County, New York. The outcrop of this series is narrow in the south part of Washington County, but it widens rapidly in Rensselaer County, occupying nearly the entire width of the county at its southern boundary. At its greatest point of development in Washington County it consists of the following strata, as shown in a section crossing the county in the towns of Greenwich and Salem, with its base 1½ miles west of North Greenwich post-office:

	Feet.
(1) Massive layers of impure, shaly limestone embedded in irregular argillaceo-arenaceous shale, with numerous fossils of the Olenellus fauna in the limestone	340
(2) Massive layers of fine-grained, bluish gray, arenaceous limestone, that become almost a pure limestone in places	670

About halfway of the mass *Lingulella calata*, *Hyolithellus micans*, and *Leperditia dermatoides* occur.

[1] The Taconic System and its position in stratigraphic geology. Am. Acad. Proc., vol. 20, 1885, table on p. 224.

[2] Geological sections across Vermont and New Hampshire. Am. Mus. Nat. Hist., Bull., vol. 1, 1884, pls. 16, 17.

	Feet.
(3) Shaly limestone in massive layers; argillaceous shales interbedded in the layers	390
(4) Calcareous, argillaceous shales, in massive layers, with interbedded arenaceous limestones below, and passing into an argillaceous shale above	240
(5) Dark, argillaceous, and arenaceous shales becoming fissile in places; occasional layers of a hard, gritty limestone 1 or 2 inches thick occur at various horizons. Near the summit of this section *Hyolithes americanus*, *Microdiscus pulchellus*, *Olenellus asaphoides*, and *Conocoryphe trilineata* occur near the roadside. This is the trilobite bed from which the original specimens described by Dr. Emmons were obtained	370
The section to this point gives a total of 2,600 feet, and is considered Division A of the section.	
(6) Compact, steel-gray, massive-bedded argillaceo-argillaceous shale, breaking into irregular fragments, and weathering a rust-brown color	2,200
At a point 1,300 feet up in this I found *Stenotheca rugosa*, *Hyolithes americanus*, and fragments of *Olenellus asaphoides*. At 2,100 feet up fragments of Olenellus occur in a stratum of calciferous shale.	
(7) Massive beds of a thinly banded, cherty, and argillaceous rock, capped by a band of calciferous sandrock	400
(8) Argillaceous shale, more or less arenaceous and calcareous throughout its extent	2,400
(9) Calciferous sandrock, light colored, weathering to a reddish brown, crumbling sandy rock. This is embedded in a calcareo-argillaceous rock, that breaks into angular fragments of a shaly character. The only fossils observed were *Obolella crassa*, Hyolithes, fragments of Olenellus, on the decomposed surfaces of the more calciferous layers	900
(10) Argillaceous and arenaceous shales, much like those of Nos. 8 and 9, with bands of bluish gray, evenly bedded, and conglomerate limestone carrying fossils. As shown in the section, this division appears to have a thickness of 4,500 feet; but it is assumed that there is much repetition by faulting, so that it is given a thickness of 2,250 feet	2,250

The combined thickness of the section to this point is 10,750 feet. Its continuity is here broken by a fault, that brings the rocks of the Hudson (?) terrane against it and between it and the purple and green slates that form a large portion of the Cambrian section east of the rocks of the Hudson (?) terrane. The section is again taken up on the east side of Salem Village, at the base of the green and purple slates and interbedded limestones, carrying characteristic Lower Cambrian fossils of the Olenellus fauna.

	Feet.
(11) Green, purple, and higher up, gray and dark shales and slates and interbedded limestones, in very thin layers	2,500
(12) Nonfossiliferous green and purple slates	2,150
In the township of Hampton to the north, the green and purple slates appear to have a thickness of 4,300 feet; and 2 miles north of that point there are over 5,000 feet of these beds, if no repetition occurs.	
The lower portion of this division is characterized by the Olenellus fauna in association with some other species that indicate the Middle Cambrian zone. The entire thickness of the lower and upper divisions, according to the section, is 15,350 feet.	
(13) Above the green and purple slate belt is a series of greenish, schistose, hydro-mica slates, estimated to have a thickness of 3,700 feet. They are not fossiliferous, and appear to pass beneath the limestones characterized	

by the Chazy-Trenton fauna. I have referred them to the Potsdam zone provisionally.[1] If this reference be correct and the rocks in the section are not duplicated by faulting, the Cambrian system has a thickness of 19,000 feet in Washington County.

This section may be greater than the actual thickness of the sediments deposited in this region during Cambrian time. The upper 3,700 feet of greenish, hydro-mica shales probably do not belong to the Cambrian, and there may be some reduplication in the section as measured. Eliminating the probable sources of error, I think there is at the least from 10,000 to 12,000 feet of strata that may be referred to the Cambrian group.

A section 35 miles to the south, across the extension of this series, exhibits a great development of the shaly portion similar to that in the lower part of the Washington County section, that passes above into the red and purple slate belt. In this section the upper member of the Washington County section is apparently represented by a coarse, greenish sandstone, and in places a fine conglomerate. At the base of this formation the red and green shales are interbedded with the sandstone, the passage from the slates to the sandstone being by intercalation of sand and slate for a distance of several hundred feet, the slate gradually diminishing in volume as the intercalation of the sandstone increases. The sandstone is estimated to have a thickness of 2,000 feet or more, and it corresponds in stratigraphic position, and is on the strike of the 3,700 feet of greenish hydro-mica schistose shales of the Washington County section. The recent work of Mr. T. Nelson Dale proves this series (Berlin grit) to be of Lower Silurian (Ordovician) age, and indicates that the series of green and purple slates beneath may represent the base of the Lower Silurian (Ordovician) and the summit of the Cambrian.

Our knowledge of the rocks of the Cambrian group in their southern extension into Dutchess County, New York, is obtained from the observations of Prof. Wm. B. Dwight. The base of the series is the "Granular Quartz" of Stissing Mountain, that had been referred to the Potsdam zone by Profs. W. W. Mather, J. D. Dana, and others. Occurring between the gneiss of Stissing Mountain and the superjacent limestone carrying the Calciferous fauna, it was natural that this should be correlated with the Potsdam sandstone about the Adirondacks; and it was not until the fall of 1886 that fossils of the Lower Cambrian or Olenellus zone were found in the quartzite, and in the limestone resting upon the quartzite.[2] Prior to this Prof. Dwight had discovered in the more or less arenaceous limestone and argillaceous shaly limestone near Poughkeepsie the presence of the Potsdam or Upper Cambrian

[1] Walcott, C. D.: The Taconic System of Emmons and the use of the name Taconic in geologic nomenclature. Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 241.

[2] Dwight, W. B.: Primordial rocks of the Wappinger Valley limestones and associate strata. Vassar Brothers Inst. Trans., vol. 4, 1887, pp. 206–214. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 27–32.

fauna.[1] It includes *Lingulepis acuminata*, *Obelella prima*, *Ptychoparia calcifera*, and *P. saratogensis*, species identical with those found at the upper horizon of the Potsdam in association with Dikelocephalus of Saratoga County, New York. Subsequently he discovered in the limestone above the quartzite, at the south end of Stissing Mountain, fossils that indicated the Middle Cambrian or Paradoxides zone. The species are *Hyolithes billingsi?*, *Leperditia ebenina*, *Kutorgina stissingensis*, and *Olenoides stissingensis*.

The stratigraphic succession is more or less interrupted by faults and the rocks are masked by the drift deposits. The succession as determined by the known stratigraphy, and the fauna is, first, at the base a massive bedded quartzite, resting upon the gneiss below, and subjacent to a bed of hard, compact limestone. In the quartzite the Olenellus fauna has been found, and in the bed of limestone immediately superjacent to it one of the characteristic fossils of the Lower Cambrian fauna, *Hyolithellus micans* occurs. In the superjacent limestone, the thickness of which could not well be determined but which appears to be considerable, the Middle Cambrian fauna was found in an arenaceous limestone, passing frequently into a calcareous shale; and in the vicinity of Poughkeepsie the Upper Cambrian fauna occurs in a somewhat similar limestone.

The contrast of the sedimentation of this section with that of Washington County is very striking. In the latter, the quartzite of Stissing Mountain is represented by the great thickness of shales, and interbedded limestones, slates, and sandstones; and the limestone of the Middle and Upper Cambrian of the Dutchess County section are entirely replaced by slates, schists, and sandstones, both in Rensselaer and Washington Counties. This difference in sedimentation is shown all along the northern Appalachian Province from Dutchess County to the Canadian border, and on to Quebec and down the St. Lawrence River to Cape Rosier. It represents the accumulation of sediments in a gradually sinking area and in a relatively shallow sea. It is a curious fact that near the old shore line the basal sandstone, "Granular Quartz" of the Lower Cambrian is almost directly succeeded by the massive limestones of the "Marble" belt. Unless there is here an area of nondeposition, the lower portion of the limestones of Berkshire County, Massachusetts, Rutland and Addison Counties, Vermont, represent the sedimentation of Middle and Lower Cambrian time.

The preceding paragraph was written several months prior to the discovery of Cambrian fossils in the limestones of the East Rutland Valley by Dr. Wolff, in 1890.

---

[1] Discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y. Am. Assoc. Proc., vol. 34, 1886, pp. 204–209.

[2] Recent explorations on the Wappinger Valley limestone of Dutchess County, New York. No. 5 discovery of fossiliferous Potsdam strata at Poughkeepsie, N. Y. Am. Jour. Sci., 3d ser., vol. 31, 1886, pp. 125–133. Vassar Bro. Inst., Trans., vol. 4, 1887, pp. 130–141.

CANADIAN EXTENSION.

The Canadian extension of the northern Appalachian district is from the United States boundary northeast to the vicinity of Point Levis, Quebec, on the western side of the extension of the Green Mountains, or Sutton Mountain anticlinal, and from Quebec down the south shore of the St. Lawrence River to Cape Rosier, Gaspé. On the eastern side of the anticlinal the supposed Cambrian rocks of New Hampshire, crossing the southeastern portion of the Province of Quebec to the Maine boundary, are also included.

The stratigraphic succession of the rocks referred to the Cambrian in the eastern Province of Quebec and down the St. Lawrence River to Cape Rosier is not yet clearly determined, owing to the faulting, plication, and absence of clearly defined Cambrian faunas in situ in the strata. In the vicinity of Quebec, on the authority of Dr. R. W. Ells, the stratigraphic succession is as follows:[1]

(1) Black, green, and gray shales, with hard and heavy bands of grayish, sometimes yellowish white, quartzose sandstone, which are thickest in the lower portion, and with occasional thin bands of limestone conglomerate, the pebbles being generally small and the paste highly quartzose. The quartzites have occasional scattered pebbles of grayish limestone.

(2) Greenish, grayish, and blackish, with occasionally dark-reddish or purplish-tinted shales, with bands of hard grayish sandstone, generally fine-grained, and in thickness from 1 inch to 1 foot, the massive quartzites being absent and many of the greenish layers being covered with fucoidal markings, well seen on the shore above Cape Rouge and in the cutting along the road above that village.

(3) Bright red shales, often with thin greenish or grayish bands, which in places are calcareous. The rocks on a smoothed surface have a striped red and green aspect; in the upper part occasional beds of a foot or more of hard green-gray sandstone occur.

(4) Red, greenish gray and black shales, with interstratified masses, often lenticular, of greenish and grayish Sillery sandstone, ranging in thickness from 2 feet upward, in which the Sillery quarries are located. This is the typical Sillery sandstone, which ranges from a fine-grained homogeneous rock to a fine quartz conglomerate, much of the rock being characterized by the presence of small flaky pieces of shale and scattered small pebbles or large grains of clear quartz, the bands of sandstone being separated by partings of various colored shale. The local and lenticular character of the sandstone is well seen in the Sillery section, some of the heaviest beds inland thinning out before reaching the shore in either direction. In the upper part, at Sillery church, *Obolella pretiosa* occurs, from which point an anticlinal crosses the river to Point Levis, and appears in the cliffs at the Victoria hotel, where the same Obolella is found.

Above the Upper Sillery Dr. Ells places the Levis shales and conglomerates of Levis City, the shore extension below South Quebec and St. Joseph and the west end of Orleans Island. In the Levis shales, the conglomerate limestone, embedded in a calcareous matrix, carries numerous bowlders in which the Upper Cambrian fauna is found; and in what is supposed to be the equivalent of No. 2, a conglomerate lime-

[1] Second report on the geology of a portion of the Province of Quebec. Geol. Surv. Canada, new ser., vol. 3, part 2, 1889, pp. 63 K, 64 K.

stone occurs in which the Olenellus or Lower Cambrian fauna is present. The thickness of the strata referred to the Cambrian is not given by Dr. Ells in his publication, but he told me that the measurements given by Mr. Logan were as nearly correct as could be determined. These were 5,000 to 6,000 feet for the Sillery and Lauzon series.

The little shell *Obolella pretiosa* ranges through from 1,500 to 2,000 feet of the Upper Sillery; and the lower or Olenellus fauna conglomerate occurs in the lower portion of this range.

Dr. Ells refers the entire Sillery series to the Cambrian, and in this I mainly agree with him, except that the upper portion is evidently a passage formation between the Cambrian and Silurian (Ordovician). On lithologic and stratigraphic evidence the line would be drawn at the summit of the red shale; on paleontologic evidence, as furnished by the Graptolites, I would include the upper portion of the Sillery red and green shales in the Silurian (Ordovician), as I think they are above the typical Potsdam zone of America.[1]

The strata doubtfully referred to the Cambrian group between Quebec and Cape Rosier, on the south shore of the St. Lawrence River, have already been described in the notice of the work of Mr. James Richardson, reported upon by him in 1870. (Ante., pp. 118, 119.) As they may or may not be of Cambrian age, no further description will be given.

The strata referred to the Cambrian on the western side of the Sutton Mountain anticlinal, or the belt extending southeasterly from Quebec to the Vermont boundary, are described by Drs. Selwyn and Ells as consisting for the most part of hard quartzites interstratified with mica-schists and black slates. All of this series, as described by them is unconformably overlapped by the Sillery red slates, conglomerates, and sandstones. Limited outcrops of grayish subcrystalline limestones are found occasionally in association with the black slates and quartzites.

The volcanic portion of the Cambrian, or group No. 2 of Dr. Selwyn,[2] presents a great variety of crystalline, subcrystalline, and altered rocks, including "coarse, thick-bedded, feldspathic, chloritic, epidotic, and quartzose sandstones, red, gray, and greenish siliceous slates and argillites, great masses of dioritic, epidotic and serpentinous breccias, and agglomerates, diorites, dolorites, and amygdaloides, holding copper ore; serpentines, felsites, and some fine-grained granitic and gneissic rocks, also crystalline dolomites and calcites. Much of the division, especially on the southeastern side of the axis, is locally made up of altered volcanic products, both intrusive and interstratified, the latter being clearly of contemporaneous origin with the associated sandstones and slates."

As far as known this zone has not afforded any fossils. Dr. Selwyn

[1] Walcott, C. D.: A review of Dr. R. W. Ells's second report on the geology of a portion of the Province of Quebec, with additional notes on the "Quebec group." Am. Jour. Sci., 3d ser., vol. 39, 1890, p. 113.

[2] Report of observations on the stratigraphy of the Quebec group and the older crystalline rocks of Canada. Geol. Surv. Canada: Report of progress, 1877-1878, 1879, pp. 6A, 6A.

thinks that if found they would indicate a lower horizon than the Levis formation, probably not far removed from the St. John group and Atlantic Coast series of Nova Scotia, or Lower Cambrian. Details of the lithologic and stratigraphic features of the strata referred to the Cambrian and their geographic distribution may be found in the reports by Dr. Ells on the Eastern Townships of the Province of Quebec.[1]

SOUTHERN APPALACHIAN DISTRICT.

The Southern Appalachian District includes the outcrops of strata referred to formations of the Cambrian group in northern and central New Jersey, southeastern and southern central Pennsylvania, western Maryland, Virginia, and North Carolina, eastern Tennessee, northwestern Georgia, and northeastern Alabama.

NEW JERSEY.

As far as known the rocks of New Jersey referred to the Cambrian are found in the northern central portion as outcrops of a nonfossiliferous sandstone resting upon Archean gneiss and subjacent to a Magnesian limestone that has been referred to the Calciferous zone of the New York section. The greatest thickness assigned to it is 20 feet.

The correlation with the Potsdam sandstone of New York is based entirely upon the lithologic characters of the sandstone and its stratigraphic position. There is no positive evidence of its being the equivalent of the Potsdam sandstone of New York. It may be Lower, Middle, or Upper Cambrian, and possibly of Calciferous age. From the stratigraphic conditions to the north and south it will probably be found to be of Lower Cambrian age, or the equivalent of the "Granular Quartz" of New York and Vermont. The lower portion of the limestone series may be of Cambrian age, as in Dutchess County, New York.

Among the papers presented to the Geological Society of America at its second annual meeting, December 31, 1890, was one by Prof. Frank L. Nason on "The post-Archean Age of the White limestones of Sussex County, New Jersey," in which he describes the discovery of the Olenellus fauna in the lower Primal sandstone of Rogers that rests unconformably upon the pre-Cambrian rocks. He said also that fossils (Obolella or Lingulella) extended up into the superjacent limestone.

In Prof. Nason's collection I recognized *Olenellus thompsoni*, Obolella or Lingulella sp.?, and the cast of a coral-like organism that is probably a species of Ethmophyllum. These were found at Hardistonville and Franklin Furnace, Sussex County, New Jersey.

---

[1] Second report on the geology of a portion of the Province of Quebec. Geol. Surv. Canada, new series, vol. 3, 1889, pp. 1K–120K.

Report on the geology of a portion of the Eastern Townships of Quebec. Geol. Surv. Canada, 1886, new ser., vol. 2, 1887, pp. 1J–70J.

DELAWARE.

The outcrop of the sandstone referred to the "Potsdam" in northwestern Delaware is very limited, and is noted only to indicate its occurrence within the limits of the State.[1]

PENNSYLVANIA.

The rocks referred to the Cambrian System in Pennsylvania by the latest authorities include the Primal quartzite of Prof. Rogers; and Prof. Lesley is inclined to consider the sandstone and slate of the South Mountain proper as of Cambrian age. The line of outcrop of the quartzite extends along the boundaries of the various Archean areas from the Delaware River on the northeast, in Bucks, Lehigh, and Northampton Counties, southwesterly, with more or less interruption, across Berks, Montgomery, Chester, Lancaster, York, and Adams Counties, to the Maryland line. Prof. J. P. Lesley's summary is as follows:

The lowest Paleozoic formation in Pennsylvania, No. 1, logically identified with the Potsdam sandstone of northern New York, makes its appearance along the edges of the limestone No. 2 at the north foot of the Azoic Mountain Range between Bethlehem and Reading in Lehigh and Berks Counties; in Mulbaugh Hill, on the Lebanon County line; in Chicques ["Chickis" of Frazer] Ridge, on the Susquehanna, above Columbia; in the Welsh Mountain in northern Chester, and in the North Valley Hill, which stretches for 60 miles from the heart of Lancaster to the Bucks-Montgomery county line north of the city of Philadelphia. Its only fossil as yet discovered is a *Scolithus*, but its position next beneath the Calciferous limestone is too well marked to admit of doubt. Formerly it entirely covered the mountain districts north and south of the Schuylkill River, because it still spreads in sheets upon their sides, and in many places makes their summits, lying unconformably upon the gneiss.

The South Mountains proper, which separate Cumberland from York and Franklin from Adams County, do not thus exhibit the fundamental gneiss covered by a coating of Potsdam, but are composed of peculiar sandstone and slate strata several thousand feet thick, which occupy the place of the Potsdam in the series, but can not certainly be identified with it. They may be considered the equivalents of the Ocoee and Sewanee strata of east Tennessee. * * * We may consider our South Mountain rocks, therefore, those lying north of the turnpike fault, as of Cambrian age.[2]

The sandstone referred to the Potsdam in Lehigh and Northampton Counties is described by Mr. Frederick Prime, jr., as "a hard, compact quartzite, of a yellowish color where weathered, and when freshly quarried of a grayish tint. * * * The thickness, where it could be measured, was 21 feet.[3]"

The quartzite varies in thickness from 20 to 300 feet, the greater thickness being in the "Chickis" section of Lancaster County, where, according to Dr. Persifor Frazer, it reaches 300 feet. Southwest of the

[1] Chester, Frederick D.: Preliminary notes on the geology of Delaware—Laurentian, Paleozoic, and Cretaceous areas. Phil. Acad. Sci. Proc., vol. 36, for 1884, pp. 237–259.

[2] A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the field work of the survey from 1874 to 1884. Second Geol. Surv. Pa., X, 1885, pp. xvi, xvii.

[3] Geology of Lehigh and Northampton Counties. Second Geol. Surv. Pa., D^2, vol. 1, 1883, p. 205.

usquehanna River it is difficult to measure its exact thickness, owing
› its disturbed condition. The characters of the sandstone appear to
e very much alike throughout the State, and the only traces of organic
emains found are the straight, vertical tubes of Scolithus.

Prof. H. D. Rogers referred a series of slates, between the sandstone,
alled Potsdam, and the base of the superjacent limestone to the Primal
eriod, but the geologists of the Second Geological Survey consider them
s belonging to the limestone series. If a comparison be made with the
'ennessee sections, where the schists and shales between the quartzite
nd the limestone are characterized by Cambrian fossils, this series of
chists will certainly be referred to the Cambrian, as it is subjacent to
he great limestone series and superjacent to the quartzite. According
› Prof. Rogers, the highest or Primal newer slate is a greenish and
luish talcose argillaceous slate, sometimes very soft and shaly, and
as a thickness of about 700 feet. Dr. Frazer refers about 1,600 feet of
Hydromica schist" to the interval between the quartzite and lime-
tone in York County.[1]

The upper part of the Primal slates does not appear to be developed to
he northeastward in Lehigh, Northampton, Bucks, Montgomery, Berks,
nd Chester Counties. It first appears with any considerable thickness
1 Lancaster County, near the Susquehanna River, and south of the
uartzites of the Chickis Hills. From thence it extends southwesterly,
cross York and Adams Counties, to the Maryland line, increasing in
hickness in Maryland and Virginia.

As a whole, the Cambrian System in Pennsylvania appears to be rep-
esented by the lower quartzite and the superjacent shales and schists
s originally defined by Prof. Rogers, and it may be that the lower
ortion of the superjacent limestone will be included.

In a letter received from Prof. Lesley, dated May 8, 1890, he says:

Reading Ells's paper and Brainerd & Seely's paper in Bull. Geol. Soc. America, just ublished, with your remarks at the meeting, I naturally reverted to my South Moun-ain surveys (20 years ago) east of Chambersburgh, Pennsylvania (Fulton and Adams ounties), and the strange and powerful impression made on me then by the outcrop f a low ridge of *purple shales*, running *from the pike southward, just back* (east) *of the estern mountain ridge*. I never saw anything like them, and feel strongly in-lined to consider them the Sillery *purple shales* (Cambrian) of the North. I can't nd or remember any description of this outcrop by Frazer. It lies in Fulton County, utside the Adams County line.

MARYLAND.

I have been unable to find any detailed account of the rocks referred
o the Primal series of Prof. Rogers, and have depended upon the gen-
ral account given by Prof. P. T. Tyson in 1860, in his report as State
gricultural chemist. His description is short and will be quoted in
ull:

(*Primal of Pennsylvania survey.*)—*Potsdam of New York.*—This division includes:
(1) A hard sandstone made up of grains of quartz, with occasionally grains of

[1] General notes.—Sketch on the geology of York County, Pennsylvania. Am. Phil. Soc. Proc., vol. , 1886, p. 401.

feldspar and kaolin. The siliceous cement seems to have completely filled up the interstices between the grains so as to give a firm compact structure to the rock. Portions of this rock seem to have been subjected to such changes as to render it doubtful whether it should not be considered a granular quartz and be classed among the metamorphic rocks. Vegetable life seems to have commenced at the period of the formation of this rock, because it contains fossilized stems of plants.

(2) A slate varying in color from gray to brownish and greenish. It is ranked as an argillite, but portions of it assume a marked talcose appearance, especially in the Catoctin Mountain and in parts of Middletown Valley, where it has been much disturbed and altered by proximity to intrusive rocks. These last consist of amphibolites (trap), porphyries, amygdaloid, serpentine, and epidote. This last-named rock is extensively developed both in large masses and intercalated between the slates, and has largely contributed to produce the highly fertile soils of Middletown Valley.

Approximate measurements of the thickness of these strata have been made in New York and Pennsylvania, but I have not as yet been able to obtain reliable information upon this point in our State.[1]

From this description and the geographic distribution of the Primal series as indicated on the accompanying map, it is evident that the quartzite of South Mountain, Pennsylvania, extends nearly north and south, across Maryland, and that the slates and associated eruptive rocks which form the main mass of South Mountain are included by Prof. Tyson in the Primal series. In the sections of these slates and accompanying rocks in Virginia they are recognized as pre-Cambrian, and it is very probable that those of Maryland and north into South Mountain of Pennsylvania are also of pre-Cambrian age. The presence of the upper Primal slate of Rogers between the quartzite and the Auroral limestone is not noted by Prof. Tyson. The fossilized stems of plants referred to are probably the Scolithus borings found so abundantly in the sandrock of Pennsylvania and Virginia. If the lower portion of the limestone series of Pennsylvania is of Cambrian age it is probable that the extension into Maryland is the same.

VIRGINIA.

Prof. William B. Rogers's description of the geographic distribution, stratigraphic position, and character of the strata that he referred to the Primal series, has been proved to be in a large measure essentially correct by the observations of geologists who have more recently studied the formations referred to the Cambrian group. He described formation No. 1 as consisting in the most part of a close-grained white or light gray sandstone, in some places containing beds of a rather coarse conglomerate of white siliceous pebbles. Near the bottom, in many instances, a brownish slaty sandstone occurs, alternating with the former, whilst toward the top or approaching the next formation the sandstone passes into reddish and brownish and olive-colored argillaceous slates. As far as known to him in his earlier work the formation in Virginia was exclusively confined to the western slope of the Blue Ridge and the narrow belt of rugged hills and mountains extending

[1] Tyson, Phillip T.: First report of the State agricultural chemist of Maryland. Annapolis, 1860, pp. 34, 35.

thence to the commencement of the Valley limestone.[1] At some later date, however, he discovered a small outcrop of the Primal series on the eastern slope of the Blue Ridge, in Rockbridge County, and drew it in on section 9 of the plates of sections published in connection with "The Virginias" in 1884. The Primal sandstones and shales are represented as occupying a narrow, deep basin on the eastern slope of the Archean rocks of the Blue Ridge. In this beautiful series of illustrations the twenty sections crossing the Primal series at subequal distances from the Potomac River to the Tennessee line illustrate very fully Prof. Rogers's interpretation of the geological structure, character, and thickness of strata forming the Primal series.

Prof. W. M. Fontaine in 1875 supplemented the work of Prof. Rogers by a detailed description of the sections of the "Primordial" strata at Balcony Falls in Rockbridge County, Rockfish Gap in Augusta County, and at Harper's Ferry on the Potomac. He concludes that the entire thickness of the Primordial strata at Harper's Ferry can not be much over 1,000 feet, and that they are composed of slaty rocks, similar to the variety of the lowest slate seen at Rockfish Gap, and a sandstone which much resembles some of the quartzites of the lower strata of the same locality. The section differs from that of Rockfish Gap and Balcony Falls in the absence of the coarser materials and the succession of shales and sandstones, with the subjacent conglomerate that rest on the Archean. The lower argillites, forming the main portion of the ridge and which Prof. Rogers included in his Primal series in section No. 2 accompanying "The Virginias," Prof. Fontaine refers to the Archean; whether of Laurentian or Huronian age, he does not undertake to decide.[2]

At the second annual meeting of the Geological Society of America, at Washington, D. C., December 31, 1890, a paper was read by Messrs. H. R. Geiger and Arthur Keith on the structure of the Blue Ridge near Harper's Ferry.

Several sections, taken on both the north and south sides of the Potomac River, show that the geologic succession at the base is a limestone upon which rests a series of shales, subjacent to a quartzite which corresponds to the Medina sandstone of the sections farther to the north and south. This section is the one described by Prof. Rogers as an *overturned section*, the quartzite corresponding to the primal quartzite of the Pennsylvania section, its present position being accounted for by the complete overturning, thus reversing the section. The authors of the paper mentioned conclude that the succession is a normal one from the pre-Paleozoic rocks through the limestone and

[1] Second report of the progress of the gelogical survey of the State of Virginia for the year 1837. Richmond, 1838, pp. 14, 15.

Geology of the Virginias, 1884, pp. 167-169.

Report of the progress of the geological survey of Virginia for 1838 (Richmond, 1839) pp. 6, 9-12.

Geology of the Virginias, N. Y., 1884, pp. 197, 198, 203-209.

[2] On the Primordial strata of Virginia. Am. Jour. Sci., 3d ser., vol. 9, 1875, p. 425.

shale to the sandstone. The basal limestone is of Calciferous—Chazy-Trenton age; the shales then would correspond to the Lorraine series, and the sandstone to the Medina series of the New York section. As as far known this is the only break in the continuity of the outcrops of the "Granular Quartz," where a quartzite is present, from central Vermont to Alabama.[1]

At Rockfish Gap the massive chloritic argillites, that form the mass of the Blue Ridge, are shown in unconformable contact with the lowest Primordial strata. The Archean argillites are firm and hard, of a dark greenish color, and present a strong contrast to the first stratum of the Primordial rocks, the line of junction being strongly defined. Summarized, Prof. Fontaine's description of the section is as follows, beginning at the base:[2]

	Feet.
(1) Very thinly laminated slates or shales	300
(2) On the side next to (1), the layers of this rock in color, do not differ much from (1), but are thicker than the preceding slates, and more sandy. The bedding thickens, and the amount of siliceous matter increases to the west, until a fine-grained white kaolin sandstone is the result	75
(3) Conglomerate of brownish-red color, in massive layers from 5 to 6 feet thick, with thin seams of shaly matter between several of the layers. The coarser materials are rounded grains of quartz of the size of a garden pea and under; inclosures of angular fragments of the slates of the Blue Ridge are not rare	60
(4) This is a partially concealed interval of 200 feet in which the rocks are, when seen, kaolin shales and kaolin sandstone, principally the former. To the west of this is a band of kaolin sandstone, with layers of cellular, much indurated quartzite, and some subordinate beds of an indurated, gray, coarse sandstone. This series contains one bed of the gray sandstone 20 feet thick. Thickness 420 feet or including the partly concealed band	620
(5) The first rock in this series is a highly indurated gray sandstone, the type of the beds above mentioned as forming occasional layers in No. (4). It is of a dark gray color, and composed of coarse grains which by metamorphic action are changed to a nearly compact texture. The thickness of the sandstone is 50 feet. A band of diorite 20 feet thick interrupts the section, next to which is a band of bluish gray, coarse shales, 75 feet wide; a partially concealed interval of 300 feet, occupied by similar rocks; then for 200 feet, several alternations of the same shales with bluish argillaceous sandstones. In these a layer 6 feet wide of red argillaceous hematite is found. Then a second band of diorite 12 feet wide, resembling in all respects the first.	
(6) The beds of No. (5) which are mostly sandy shales, and are rather thickly-bedded in layers of from 1 to several feet, are succeeded by a band of very thinly-laminated, firm olive slates or shales, having a total thickness of	300
Indurated brown sandstone, with some chlorite	30
Interval of concealed rock	100
Alternations of brownish argillaceous sandstones with greenish shaly beds	150
Very finely fissile, pink-colored slaty shales, which weather purplish-red	200
Then for 100 feet a bluish shale is found	100
	880

[1] Bull. Geol. Soc. Am., vol. 2, 1891, pp. 155–163.

[2] Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 416–421.

Feet.

The two last series of beds, 5 and 6, appear to be the equivalent of No. (9) of the Balcony Falls section. Their combined thickness is about 1,450 feet, that is, provided no reduplication from folding occurs. This is possible, though not probable, I think.

"The strata now to be described are the equivalent of the Potsdam sandstone, and resemble No. (10) at Balcony Falls in their almost total freedom from iron and other coloring matters. * * * The system here consists of a vast number of thin layers, in which we may distinguish three classes of rock: (*a*) A shale pale gray to bluish gray when fresh, composed almost entirely of kaolin, and occurring in thin plates. (*b*) This is associated with a very fine grained kaolin sandstone, the quartz grains being now perceptible to the naked eye. * * * (*c*) A kaolin sandstone of moderately fine grain, often with a thickness of several feet in the individual layers. The quartz grains are mixed with an equal amount of kaolin 300

'The beds last described have a thickness of 300 feet, and are succeded by a partially concealed interval, in which 50 feet of a similar ck are shown." The strata between this point and the Auroral limeone are largely concealed.

The section as studied at Balcony Falls by Prof. Fontaine is as follows:[1]

	Feet.
Unbedded quartzite, with crystals of feldspar	120
Brown, crumbling, argillaceous rocks or sandy shale, conglomerate in its upper portion	40
Brown, decomposing, thinly laminated and contorted shale	10
Conglomerate, like the upper portion of (2)	20
Shales, like (3)	12
Conglomerate, like (4)	15
Crumbling, brownish shales, passing in the upper portion into argillaceous sandstones of the same hue and texture	200
Massively bedded, coarse white quartzite (apparently Rogers's typical No. 1)	500
Up to this point the rocks are well exposed in the cliffs which closely border the canal. Proceeding west across the strike, we next encounter a series that forms No. (9).	
Thinly laminated, gray and reddish shales. Probable thickness	600
) Alternating beds of quartzite and kaolin shales. Probable thickness	700
) The first rock seen next to the mountain is thinly laminated, fragile shale, of yellowish and reddish hues not fully exposed. Next, to the west, we have bluish calcareous slate, and slaty limestone, 50 feet. Then very thinly laminated, firm, deep red slates, 60 feet. Next a similar slate of blue color, 15 feet. Then a bed of dark blue, hard, and dense limestone, used for cement, 13 feet. Then thinly laminated red slates, 20 feet. Then coarser and thicker bedded blue slates, 40 feet. Lastly, a coarse, rough, massive, siliceous limestone, 40 feet	238
	2,455

He compares the Balcony Falls section with that of Rockfish Gap, ting that the thickness of Nos. 5 and 6 in the latter section is much ater than that estimated for their equivalent, No. 9 in the Balcony

[1] Am. Jour. Sci., 3d ser., vol. 9, 1875, pp. 363–365.

Falls section, showing that the proportion of shaly matter in the entire group at Rockfish Gap has greatly increased.[1]

In summing up the physical characters of the sections as described, he says:

It will be seen from the above notes that in Virginia we have below the calciferous limestones a great development of sandstones, shales, and conglomerates, which attain in the middle portion of the State a thickness of over 2,000 feet, and increase in the proportion of coarse materials to the southwest. They probably attain greater thickness in that quarter, while to the northeast the amount of sediment diminishes, and the proportion of fine matter increases. This change is plainly due to the increasing development to the southwest of the syenitic rocks which formed the shores of the ancient seas and to the greater violence in that direction of disturbing forces. The Potsdam sandstone forms one of the upper members of this group. Much further study of these strata is required to settle the question whether the entire series is a great expansion of the Potsdam or whether divisions may be made corresponding to other epochs. The fact that at Rockfish Gap, and to the southwest, a great body of ferruginous slaty shales separates the lower highly siliceous and altered, sandstones from the upper Kaolin sandstones of probable Potsdam age, seems to indicate a change in the conditions of sedimentation sufficient to justify such a division, in which the Acadian strata may be found.[2]

With the single exception of a Scolithus, no fossils have been found in these rocks which would indicate their age.

In 1883 Prof. Fontaine supplemented his detailed description of the sections by a synoptic description, embracing the general character of all the formations that he considered belonging to the Primordial series.[3] Beginning with the base of the Primordial he recognized six divisions as follows:

	Feet.
1. Lower Primordial conglomerate	0 to 30
2. Lower gray shales and flags	500
3. Red shales and flags	400
4. Upper gray shales and flags	600
5. Potsdam quartzite	350
6. Ferriferous shales	500
	2,380

The description of the various formations is so clear and full that I quote them:

(1) *Lower Primordial conglomerate.*—I would confine this appellation to the lowest conglomerate that forms the base of the Primordial where it is present, excluding the conglomerate bands that follow higher up, but are separated from the basal conglomerate by shale and slate. * * * This member, thus limited, I have not seen at all the places where the junction of the Primordial with the Azoic is exposed. * * *

The conglomerate now in question is of special importance, since, when it is found, we may be sure that we have the true base of the Primordial. I have never seen it without finding the Azoic rocks immediately under it. It consists of a finer matrix that is shaly or slaty in texture, in which particles, angular or rounded in shape, of the Azoic strata are imbedded. The lithological character of the pebbles varies

[1] Op. cit., p. 421.

[2] Op. cit., p. 424.

[3] Notes on the mineral deposits at certain localities on the western part of the Blue Ridge. The Virginias, vol. 4, 1883, pp. 22, 42-44.

with the nature of the adjoining Azoic. To the south they are more commonly composed of gneissoid rock, but to the north the Huronian schists furnish the material. * * *

In the more southerly portions of the belt a good deal of partly decayed feldspar may be detected in the finer matrix, but to the north argillaceous material forms the cementing matter (p. 22).

(2) *Lower Gray Shales and Flags.*—The lower portion of this member of the Primordial frequently contains bands of conglomerate, composed of quartz pebbles, often purplish in color, imbedded in a fine-grained matrix of shale or slate * * * (p. 42).

The lower gray shales and flags vary in character more than any other member of the Primordial. The predominant rocks are shales, that sometimes become slaty in firmness and thinness of lamination, or various more siliceous flaggy rocks that range from purely argillaceous shales, through argillaceous sandstones, into massive and highly siliceous quartzites. These latter have the character described above. The predominant color is gray, but reddish, yellowish, or purplish and greenish colors sometimes occur.

Some of the grayish white, argillaceous strata form a species of claystone that weathers to a sort of kaolin. For the sake of distinction these may be called kaolin flags. This kind of rock is much more common in the member next under the Potsdam quartzite. The conglomerates occurring in the lower part of this member have been already described.

The general features of the quartzite members of this group have been already sufficiently discussed. Towards the southern portion of the belt, they attain great dimensions. This is especially true of the space between the southern border of Augusta County and Balcony Falls. At this latter place a quartzite formation occurs about 150 feet above the base of the Primordial, forming the Balcony Rock. It lies in huge beds of a highly siliceous character, and is not less than 250 feet thick. Here the massive character of the beds has prevented the cracking and smashing, accompanied with the infiltration of silica, so often seen in the smaller beds of quartzite at this horizon in other places; otherwise the character is as given above for the lower quartzites. I have never seen any casts of Scolithus borings in these quartzites. The great quartzite at Balcony Falls disappears almost entirely in the northern portion of the belt, its place being taken by minor beds of quartzite, and by shales and flags. The subdivision of the Primordial beds now being described forms the lower portion of the Primal older slates of the brothers Rogers.

(3) *Red Shales and Flags.*—This also is quite a variable group, and it changes its character very materially as we go south. In the northern portion of the belt, as far as Mount Torrey, the greater portion of this group is composed of a fine-grained, very thinly laminated, and tender slate. When fresh this rock has a steel gray color and pearly or nacreous luster, but on weathering many portions become deep blood red in color. Some of the lower and upper portions become yellow, but red is the predominant color from weathering. Some bands have small pebbles of the size of bird shot graduating into sand. Some of the red and yellow colors may be original and not due to weathering. This can not be decided, as all the exposures seen were much weathered. This member, in its northern exposures, is often affected by faults that cause it to extend over greater breadths than it could occupy in virtue of its thickness. Quartz veins occur in it, having the nature of fissure veins. Bands of this slate are impregnated with more or less specular iron, and this is the highest member of the Primordial that shows iron in the specular form. Some greenish, much indurated quartzite occurs in this member. This group to the south becomes more siliceous and the amount of red coloring matter diminished.

At Big Mary Creek the slaty character is nearly lost and the amount of red matter is much less. The strata are now chiefly rather siliceous gray flags, and this character is maintained to Balcony Falls; there the rocks at this horizon are nearly all

flaggy and gray in color; some reddish and brownish beds, however, are found. This change to a more siliceous nature is accompanied by a great increase in the accompanying quartzites. These strata everywhere, owing to their comparatively greater capacity for yielding to strains, have suffered much from contortions and minor faults.

(4) *Upper Gray Shales and Flags.*—This group, as the name implies, is somewhat like No. 2, but in it the conglomerates and specular ledges are wanting and the amount of quartzite is usually much less. Owing to the brittleness of the material of the beds and the ease with which many of them yield to crushing, portions of the strata are often found crushed to loose fragments. In the fractured and crushed portions important deposits of limonite are sometimes found that are evidently produced by the concentrating action of percolating waters. The reddish and brownish rocks found in No. 2 are also wanting here. The predominant rocks are shales and flags, usually all highly argillaceous, and when fresh of a gray or greenish gray color, but on weathering apt to assume a grayish white color. Towards the top quartzite ledges are interstratified with these and cause a gradual passage into the Potsdam quartzite. In some places the amount of quartzite here is very large and should properly be counted as a portion of the Potsdam member of the Primordial. Perhaps the predominant rock is a gray shale that resembles a hardened mudstone and which graduates into a sandy shale. This rock often decays to a pure white clay, and no doubt furnishes the material for the pure potter's clay sometimes found immediately west of the Blue Ridge. These strata for the sake of distinction may be called kaolin shales or flags.

(5) *Potsdam Quartzite.*—The members of the Primordial below this, so far as observed by us, show no indications of the former existence of life. This portion of the formation, however, shows in some beds numerous casts of Scolithus borings, some of which are remarkably long, being visible for at least 3 feet. The brothers Rogers considered this member as identical with the Potsdam sandstone of New York. This portion of the Primordial is more constant in lithological character than the subdivisions that underlie it. Quartzite is always the predominant rock in it, the remaining portions being mostly composed of the kaolin shales and flags. To the south, and especially in the interval from Mount Torrey to Buena Vista furnace, the quartzite is very massive and siliceous, composing nearly all of the rock at this horizon. The material is more properly called a quartzite than a sandstone. The upper and lower portions are often flaggy, and cause a passage into the underlying and overlying shales and flags. So far as observed, these quartzites are never conglomeratic, and they are free from the infiltrations of silica, the diffused chlorite, and other characters that mark the lower quartzites. Near the junction of this member with No. 4, the strata are often crushed, the crushed band holding important deposits of a dark limonite. The Quartzite members of this subdivision are sometimes broken up and crushed, forming a curious band of breccia, cemented by iron or manganese. Sometimes workable deposits of limonite are found in these disturbed portions.

(6) *Ferriferous shales.*—It might be a question whether these shales ought not rather to be counted with the Calciferous group. It is certain that there seems to be a gradual passage from the shales into the pure Magnesian and Siliceous limestones, that correspond to the Calciferous sandstones of New York. No fossils are found to settle the matter, and it seems best to draw the dividing line at the first marked change in the lithological character of the strata. This change occurs with the lowest limestone beds, that usually occur interstratified with reddish and yellowish shales.

The Ferriferous shale group is noteworthy for containing throughout it deposits of limonite which are often suited for the manufacture of a neutral iron. These deposits seem to be of concretionary origin, formed by the decay of the shales which contain the iron in a diffused form, probably, for the most part, as a carbonate, but sometimes as pyrite. These ores are consequently usually imbedded in clay. They

assume the form of lenticular masses, usually built up of concretionary forms. These ores are unlike those found in and under the Potsdam sandstone, and not rarely are mingled with oxide of manganese or associated with it, forming ferro-manganese. In the same shales, occurring under conditions similar to the iron and formed in like manner, we find, not rarely, deposits of quite pure manganese oxide. This is always in the form of Psilomelane or hard manganese.

The lowest of the strata of this group have the character of kaolin shales and flags. They graduate insensibly into the Potsdam quartzite member. In ascending they become purely argillaceous shales, generally of lead, or bluish gray color, when fresh. With these, moreover, occur strata yellowish-reddish in color, the red often assuming a pinkish shade. Towards the top, ledges of pretty firm pure purplish shales and flags are found that are sometimes of the nature of fine-grained sandstone. The shales towards the top are often calcareous, and graduate into the impure limestone with which the Calciferous group may be assumed to begin.

We thus have in the Primordial formation, in the belt now being described, at least three horizons of iron ore. The lower strata contain specular iron ore usually of low grade, the middle portions, extending as far as the Potsdam quartzite, containing limonites, either impregnating definite strata, or filling what were once fissured and crushed bands. Hence all of these usually appear in massive or rocky outcrops. Finally, in the Ferriferous shales, we have interrupted deposits of limonite, inclosed in clay and often mixed with manganese. (No. 12885, U. S. G. S. Library.)[1]

The Balcony Falls section has also been studied by J. L. and H. D. Campbell with a slightly varying result. As measured by Prof. J. L. Campbell the section is as follows:

	Feet.
1. Conglomerates	50
2. Sandstones	350
3. Slates	600
4. Sandstones (thickness not given).	
5. Slates	180
6. Scolithus sandstone	340
7. Shales	600
Total	2,120

A comparison of this with the sections measured by Prof. Fontaine, in 1879, shows essentially the same succession of strata, although differing materially in the thickness of the various divisions based on the character of the rocks. Subsequently, Prof. Campbell added to the preexistent information of the section at Balcony Falls, by showing that the primal series is present upon the southeastern slope of the Blue Ridge, a short distance north of the James river. This was followed by a paper on the Snowdon slate quarries, by himself and his son, in which it is said that the sandstones are penetrated with Scolithus and dip beneath the Snowdon roofing-slate quarries.[2] An accompanying ideal section, crossing the Blue Ridge 3 miles north of James River Gap, represents the Primal series at the summit dipping to the westward and on the eastern slope dipping at a high angle to the eastward and resting unconformably upon the Archean gneiss.[3]

[1] Op. cit., p. 43.

[2] The Snowdon slate quarries. The Virginias, vol. 5, 1884, pp. 162, 163.

[3] Op. cit., p. 170.

Prof. J. L. Campbell concludes, from the structure, that this portion of the Blue Ridge has been formerly spanned by a grand arch or series of arches of Cambrian strata, upturned, perhaps, at the time of their upheaval.[1]

In 1885 Mr. H. D. Campbell published a more detailed section of the Blue Ridge at Balcony Falls, to illustrate the view that the Blue Ridge at this point is a portion of an antic linal fold, over which the Cambrian strata formerly extended from the west to the east, forming a synclinal basin on the western side of the Blue Ridge. He described the Cambrian section at Balcony Falls as follows:

	Feet.
1. Conglomerate	120
2. Sandstone	360
3. Slates	500
4. Hard sandstone	150
5. Slates	700
6. Sandstone	90
7. Slates	120
8. Scolithus sandstone	350
Total	2,390

He further states that, away from the river some distance, there is about 600 feet more of sandstone and friable slate before reaching the limit of the Potsdam formation.[2] This gives a greater thickness to the Cambrian section of Balcony Falls than that measured by either Prof. J. L. Campbell or Prof. Fontaine.

The next complete description of the Cambrian in the southwestern portion of the State is that of Prof. J. J. Stevenson, in his account of a reconnaisance of Bland, Gyles, Wythe, and portions of Pulaski and Montgomery Counties. On the map accompanying the paper, the geographic distribution of the Cambrian rocks is shown for Montgomery, Pulaski, and Wythe Counties. He includes in the Cambrian the lower Knox shales and the Potsdam, stating that the former are probably equivalent to the hydromica schists of Pennsylvania and the lower part of the Calciferous of New York; the latter is the Potsdam of New York, vastly increased in thickness.[3] The Knox shales are described as being reddish, sometimes streaked with white color, usually more or less greasy, often talcose-looking on the slipped surfaces. The shales are hard enough to form bluffs. The thickness could not well be ascertained, but it can not be less than 600 feet.

The Potsdam forms the great mass of Lick Mountain, is the sandstone of Draper Mountain, and is found along the southern border of Wythe, Pulaski and Montgomery Counties. The upper beds are alternations of sandstones and shales.

[1] Geology of the Blue Ridge near Balcony Falls, Virginia; a modified view. Am. Jour. Sci., 3d ser., 1884, vol. 28, p. 223.

[2] The Potsdam group, east of the Blue Ridge, at Balcony Falls, Virginia. Am. Jour. Sci., 3d ser., vol 29, 1885, p. 472.

[3] A geological reconnaissance of Bland, Giles, Wythe, and portions of Pulaski and Montgomery Counties of Virginia. Am. Phil. Soc. Proc., vol. 24, 1887, pp. 86, 87.

The base of the series was not observed by Prof. Stevenson, but he thinks that the sandstone of Draper Mountain is not less than 2,000 feet in thickness. The only fossils observed were *Scolithus linearis*, on Lick Mountain.

In Dutchess County, New York, on the north, and in Tennessee on the South, the lower portions of the limestones are of Cambrian age. Whether the same is true of the arenaceous limestones above the Cambrian shales is one of the problems to be studied in Virginia.

NORTH CAROLINA.

The Cambrian rocks in North Carolina are the extension across the border from Tennessee of the Chilhowee series with, perhaps, some of the Knox shales. The best section is that along the line of the French Broad from Paint Rock on the State line eastward up the river to the vicinity of Warm Springs. The Paint Rock sandstone apparently is the representative of the Chilhowee sandstone, and the shales the Knox shales, or Upper Cambrian. The relation of the other portions of the section on the French Broad to these formations is, as yet, undetermined.

TENNESSEE.

Ocoee conglomerate.—The descriptive details of the Cambrian rocks of Tennessee are almost entirely derived from the work of Prof. J. M. Safford as published in the "Geology of Tennessee" in 1869. A large amount of additional data has been obtained by the geologists of the U. S. Geological Survey. At my request Mr. Bailey Willis, chief of Appalachian Division of Geology, prepared the following notes upon the geologic position of Prof. Safford's Ocoee formation:

The Appalachian Paleozoic area is bordered on the eastern side by a belt of clastics of very great thickness, which forms conspicuous ridges between the Archean granites and the calcareous Paleozoic strata. The slates, sandstones, and conglomerates of this belt, characterized by lithologic similarities among themselves and distinguished by marked lithologic contrasts from other rocks, fall into a natural group. Semimetamorphic, they occupy mineralogically a position between the crystallines and the unaltered sediments. Resting in many localities directly on the Archean and containing fragmental granitic minerals, their apparent stratigraphic position is also intermediate between the Archean and the unaltered sediments. For these reasons, and in the absence of fossils, they have been placed by all the older geologists at the base of the stratigraphic column. Structural facts sometimes fall in with this stratigraphic arrangement, and where they do not faults have been assumed to account for the superposition of the supposed older on younger strata.

In Tennessee the type localities of these clastics are Chilhowee Mountain and the Ocoee gorge, and quartzites of the Chilhowee type, but not in Chilhowee Mountain, have been correctly placed above slates of the Ocoee type by Safford. Your own discovery of fossils in the upper shales of Chilhowee Mountain appears to determine the age of all these sediments as Lower Cambrian or pre-Cambrian. But there is an assumption which must be sustained, or the conclusion fails in its broad application. That is, that the natural grouping of these strata by physical characters into a single series proves them to be of one period; this may be the result of similar conditions which existed at different periods, and the natural group may include strata of widely

separated horizons. The latter is the fact. The Chilhowee formation in Chilhowee Mountain has been proved by fossils to be Lower Cambrian, but it is a synclinal mass isolated by faults, and the definite determination does not apply beyond its limits. It is not connected with the Ocoee area, and the Ocoee rocks in the type locality are so separated from strata of known age, that nothing definite can now be asserted as to their correlations. Starrs Mountain, a "Chilhowee" outlier 24 miles southwest of Chilhowee Mountain, contains a fossiliferous limestone apparently conformably underlying the quartzite; if further study confirms this apparent relation, the quartzite is near or above the top of the Lower Silurian. Meadow Creek Mountain and the Big Butt range, extending from 25 to 70 miles east by north from Chilhowee Mountain and assigned by Safford to the Chilhowee and Ocoee formations, are determined on stratigraphic and structural evidence to belong to the Nashville period, the last of the Lower Silurian deposits. "Ocoee" strata of Safford, occurring southeast of Chilhowee Mountain about Cades, Tuckaleechee, and Weirs Coves, are known to belong to the Nashville on evidence of strict structural conformity to the Knox dolomite over three extensive quaquaversals and through transition beds from the dolomite to the slates. The Nashville "Ocoee" strata in this locality and in the Big Butt exceed 12,000 in thickness and form some of the highest ranges along the North Carolina boundary.

If, as these facts prove, the great natural group of clastics along the eastern Paleozoic border is the result of conditions repeated in different periods, we should seek an explanation for recurrence of like conditions, and this is found in the relative extent of subsidence in the Cambrian and Silurian times.

The Cambrian sea transgressed over the granitic continent under such conditions that the constituent minerals entered into shore deposits, without complete decomposition; these conditions probably existed in the deep disintegration of the granite, as suggested by Pumpelly. The subsidence ceased during Knox time and the deposition of the Knox was followed by uplift which exposed the dolomite to the waves of the Nashville sea. The evidence of this and of subsequent subsidence is found in conglomerates of Knox dolomite at the base of and interstratified with the strata of the Nashville-Ocoee in many localities. The beds associated with these conglomerates are arenaceous shales and sandstones, but higher in the Nashville series conformably stratified with these, and extending to basal conglomerates resting on the Archean, are deposits containing granitic fragments like those of the Cambrian-Ocoee. The stratigraphic and geographic relations leave no doubt that the Nashville was a period of great transgressions beyond the limits of any previous subsidence, and the deposits derived from the granites in the later time were identical with those earlier accumulated from the same source.

The semi-metamorphic character of both Cambrian and Nashville-Ocoee strata demands explanation which may possibly be found in their original composition and in their common relations to thrust and resistence during Appalachian formation. Both series of rocks are thin bedded piles, both rest against the unyielding Archean masses. Whatever pressure they received they were forced to conform to and they appear to have suffered changes of form, which were both mechanical and chemical and which were induced by dynamic conditions.

The generalizations herewith submitted are derived from the detailed work of Messrs. Arthur Keith and C. Willard Hayes as well as from my own studies and the conclusions as to the age of formations have been reached through mutual cooperation.

Chilhowee sandstone.—The lithologic character of the Chilhowee sandstone is given as follows by Prof. Safford:

It is a great group of heavy-bedded sandstones, often dark, but generally weathering to a grayish white, and containing great beds of whitish quartzose sandstone, or quartzite. Interstratified with the heavy-bedded rocks are, at some points, sandy shales, and thin flags, often containing scales of mica. Some of the sandstones are coarse

and approach fine conglomerate. It may be mentioned, too, that not unfrequently the strata have green grains (glauconite) disseminated through them.

The sandstones of this group very often show the worm-holes, and the sandy rods within them, belonging to Hall's species *Scolithus linearis*. It is the exception not to meet with them. In addition to these, the surfaces of the strata sometimes show impressions of fucoids. No other fossils, that I know of, have been found in this horizon of Tennessee.

This formation is by no means as thick as the Ocoee series; yet it has volume enough to form conspicuous mountain ridges. It is not easy to determine its thickness; its maximum is not less, however, than 2,000 feet, and it may be considerably more.[1]

This general description is followed by the detailed description of a number of sections. The lithologic features of this formation are much the same in all of its presentations, from Virginia to Georgia.[2]

Knox sandstone and shale.—In the table of geological formations the Knox group is next in order above the Chilhowee sandstone, and its basal member is formed by the Knox sandstone.[3] The principal rocks of the Knox sandstone are hard shales and thin sandstones, heavier sandstones being interstratified with these. The heavier sandstones are fine or coarse grained, sometimes quartzose. They occasionally abound in green grains. In the section of Webb's Ridge, near Knoxville, the hard, dark, gray sandstone referred to occurs six times in beds from three to ten feet thick, and weathers into a buff, softer material. In general, the included layers vary much in appearance. As before stated, beds of dolomite are met with in the division.[4]

The thickness of these rocks can not be much less than 800 or 1,000 feet. In Webb's Ridge, where they are in less force than at many other points, the thickness is 540 feet.

The strata are often ripple-marked, and sometimes covered with fucoidal impressions and ridges. Aside from fucoids, I have not met with any fossils in these rocks. * * *

It may be mentioned as a prominent feature of this division and of the Knox shale overlying it that they present shales and sandstones of many different colors. The rocks are pale green, brown, and red, chestnut-colored, buff, gray, and other colors. Brownish red, greenish, and buff are, perhaps, the prevailing tints. The colors are often bright, and notably agreeable.

In reading the description of the Knox sandstone by Prof. Safford, I have failed to find any general or detailed section or description that connects the Chilhowee sandstone and the Knox sandstone. Apparently there is not any section known in which the two are seen in stratigraphic relation to each other. From the character of the section and the sedimentation, it may be that the Knox sandstone is the representative of a portion of the Chilhowee series, the former being the off-shore deposit, while the Chilhowee sandstone accumulated near the shore.

The Knox shale is largely a variegated shale, with interstratified beds of thin layers of blue limestone, which is often oolitic.

[1] Geology of Tennessee, pp. 198, 199.
[2] Op. cit., p. 158.
[3] Op. cit., 1869, p. 203.
[4] Op. cit., p. 209.

The calcareous bands in the lower part of the division are not numerous; toward the top, they generally become more abundant, increasing as we ascend, until finally the shales disappear, and the blue ooliticlime'stone, and dolomites are the only rocks. In this way the shale division runs into the uppermost one.

In the northeastern part of the State the shales, as a division, are not well characterized. As already stated they are much mixed with beds of limestone and dolomites, and lose, in good part, their distinctive features. Moreover, in this region there is little oolite rock. A portion of the shale appears to be replaced by a blue limestone containing thin clayey seams, which give the surface, especially when weathered, a striped appearance. This striped rock occurs, too, further south, its place being at the top of the shale.

The thickness of the Knox shale is not easily determined. What is said in reference to the thickness of the strata in Poor Valley * * * applies generally. We may place it as an approximation at 1,500 or 2,000 feet.[1]

Prof. Safford states that fossils occur in a blue limestone intercalated with shales, sometimes quite abundantly, both in the compact and oolitic layers. Toward the top of the division and in the blue rocks of the succeeding division they are seen at many points. The shales themselves are occasionally fossiliferous. It was his intention to describe the species in the appendix of the volume, but we find only a list of names, as follows:[2]

Crepicephalus similis, Safford.
roanensis, Safford.
tennesseensis, Safford.
Lonchocephalus fecundus, Safford.
Agnostus arcanus, Safford.
Lingula prima?, Conrad.

A large collection has been made within the last few years at the localities from which he obtained his specimens, and from many others in Tennessee, that indicate this fauna to be a portion of the Upper Cambrian or Potsdam fauna. The same fauna extends up into the base of the limestone for a short distance. The entire dolomitic series is referred to the Knox group by Prof. Safford, but I think that the line of demarcation must be drawn near the base of the dolomite.

As a whole, the Cambrian group in Tennessee is represented by a great series of sandstones at the base, succeeded by a series of shales that become more and more calcareous toward the top, where they pass into the dolomitic series, forming the base of the Silurian (Ordovician) system. During the progress of the resurvey of eastern Tennessee by the geologists of the U. S. Geological Survey Dr. Cooper Curtice found a few fossils in the shales interbedded in the quartzite of Chilhowee Mountain, and in 1889 I found a few specimens in the shale about 20 feet above the quartzite in the upper shale bed. The study of the fossils collected by Dr. Curtice and myself proves that the Olenellus or Lower Cambrian fauna occurs in the shales of the quartzite series of Chilhowee Mountain. This fauna, with that found in the upper portion of the Knox shales and the base of the dolomite, gives two distinct

[1] Op. cit., p. 211. [2] Op. cit., p. 212.

horizons in the Cambrian of Tennessee—the Lower Cambrian and the Upper Cambrian. Between the two there is an unknown thickness of shale, in which fossils have been found sparingly, but not in sufficient numbers to determine the presence of the Middle Cambrian fauna. If the definition that the base of the Cambrian is to be drawn at the lowest horizon in which the Olenellus fauna is found is applied in Tennessee, the Chilhowee sandstone will be referred to the Cambrian.

GEORGIA.

The published information relative to the Cambrian rocks of Georgia is largely contained in the work of Mr. George Little. It is summed up in the compilation prepared for the Department of Agriculture, under the direction of Mr. Henderson, as follows:

Acadian.—Along the western escarpment of the Cohuttas exist beds of semimetamorphic slates, and conglomerates, apparently of very great thickness. To this formation, in Tennessee, has been given the name of Ocoee group, from the Ocoee River, along which, near the line of Tennessee and Georgia, the rocks appear to have their greatest development, or at least are most prominently displayed.

The group as yet is not known to contain fossils, but has been referred on the ground of its supposed stratigraphic relations to the Acadian epoch. A sandstone of several hundred feet in thickness is conspicuously displayed in steep ridges or mountains skirting the western base of the Cohutta, Pine Log and Allatoona Mountains. This is the Chilhowee sandstone of Tennessee, and is believed to be the equivalent of the Potsdam sandstones. In Tennessee, *Scolithus* impressions—worm holes filled with sandy rods, somewhat softer than the body of the rock—are mentioned as a common characteristic of the sandstone by Prof. Safford, and indicate a probable identity in age with the Potsdam sandstone of New York. These markings have not yet, so far as known, been observed in this State, but the sandstones are often filled with small rounded concretions, that disappear from the weathered surface, and give much the appearance presented by a cross-section of the Scolithus rods in sandstone.

This is succeeded by hard glauconitic shales and glauconitic sandstones, associated with siliceous limestones, found in a broad belt of country along the Coosa River, and give rise here to what is known as the Flatwoods. Some portion of the same group is found in a belt of country in the eastern portions of Gordon and Bartow and the southern part of Murray, and also come to the surface again for a few miles in sterile ridges on the western side of Whitfield County, between Dick's Ridge and Chattoogata Mountain. Trilobites are found in some of the shales and limestones, and are abundant in the Flatwoods, near Livingston, in Floyd County.

A prominent mineral characteristic is the common appearance of green sand or glauconite in the shales and sandstones, and sometimes in the limestones. This green sand may be found, on close examination, in most of the shales and sandstones, and is sufficiently abundant in some to give them a decided green color. * * *

Knox shale.—Shales and limestone of an estimated thickness of 3,500 feet. The shales are more or less calcareous, and are generally of a light green shade of color, below the water surface, but weather into a great variety of shades from buff to red, blue, green, brown and black, but is most generally some shade of brown. These shales exist in all the counties in northwest Georgia except Dade, and are found in a number of long valleys, varying from half a mile to 1 or 2 miles in width, constituting a large part of the area of cultivated lands in this section of the State. Among these are the Oothkalooga Valley of Bartow and Gordon, the Coochulle and Dogwood Valleys of Whitfield, and the Chattooga Valley of Walker and Chattooga.[1]

[1] Henderson, J. T.: Geology (of Georgia). The Commonwealth of Georgia; the country, the people, the productions. Atlanta, 1885, pp. 83, 84.

As noticed in the historical review, Mr. McCutchen's estimates of the thickness of the formations referred to the Primordial is 8,000 feet, and to the Knox shale series 2,400 feet, making a total thickness of 10,400 feet. The estimates of the author we have just quoted assign to the Knox shale a thickness of 3,500 feet, which will give a still greater thickness for the total Cambrian section. I think, however, that all such estimates must be carefully revised, as the rocks of the Knox shale series are very much disturbed by plications and faulting.

An unpublished section, by C. Willard Hayes, of the Appalachian Division of the U. S. Geological Survey, extending from Rome, Georgia, to Gadsden, Alabama, gives the following series, extending from the top downward:

			Feet.
Silurian.		Knox dolomite	4,000–5,000.
Cambrian.	Connasauga shale.	Thin bedded seamy limestone, sometimes blue and massive.	
		Yellow shales, calcareous, grading into seamy limestone.	
		Earthy limestone interbedded with shales, often wanting; locally carries nodules of chert.	
		Yellow shales.	
		Oolitic limestone; thin beds in light green or yellow shales.	
		Variegated sandy shales, purple, green, brown, etc	1,600–2,000
	Rome Sandstone and Weisner Quartzite.	Thin beds of highly colored sandstone: red, purple, and green; show ripple marks and sun cracks. Beds 1 to 12 inches thick with interbedded shales. Maximum thickness shown between Rome, Georgia, and Big Cedar Creek	1,300–1,800
		Green shales, with thin, hard, siliceous beds, ¼ to 2 inches thick, or layers of flat nodules. Maximum thickness at Georgia-Alabama line	700–1,500
	Coosa shales.	Fine yellow or brown shales, containing some beds of blue limestone	1,000±
		Heavy beds blue, seamy limestone	600±
		Yellow or green clay shales, with thin beds of blue limestone contorted and filled with calcite veins. Sometimes the shales contain siliceous nodules. Always highly contorted. Cover a large area between Rome and Gadsden, and form the "Flatwoods" of Coosa Valley. Thickness not known; probably not less than	3,500

In a recent paper on the valley rocks of northwestern Georgia, Mr. Hayes assigns a thickness of 1,600 to 2,000 feet to the Connasauga (=Montevallo of Smith) shales; 2,000 to 3,500 feet to the Rome sandstone and Weisner quartzite, and 3,000 feet plus to the Coosa shales.[1]

In a section at Mount Weisner, Alabama, Mr. Hayes found a quartzite that he considers to correspond to the Rome sandstone. It has a thickness of about 800 feet, and is in the form of lenticular masses of white quartzite; sandstone and conglomerate occur at the base and

[1] The Overthrust faults of the southern Appalachians. Bull. Geol. Soc. America, vol. 2, Feb., 1891, p. 143, pl. 3.

replace a portion of the Rome sandstone. In Indian Mountain it is much thicker than in Mount Weisner, and consists of several beds of quartzite, with intervening masses of yellow sandy shales.

The fossils collected from the Coosa shales by Dr. Cooper Curtice indicate, as studied by me, the Middle Cambrian fauna of the northern Appalachian section. The Connasauga shale is correlated by its stratigraphic position with the Knox or Upper Cambrian shales of the Tennessee section. In Mr. Hayes' table the Rome sandstone and Weisner quartzite are placed on the same horizon with the Knox sandstone, Potsdam or Chilhowee of Smith and Safford. That the correlation by Messrs. Smith and Safford of the Weisner quartzite with the Chilhowee is probably incorrect is supported by the fact that the fauna of the Coosa shales belongs above the Chilhowee sandstone in sections where the succession is undisturbed. The Chilhowee sandstone fauna is the type of the Lower Cambrian, and the Coosa shale fauna is that of the Middle Cambrian.

When the maps of the Paleozoic region of Georgia and Alabama are published geologists will have the data for the geographic distribution of the Cambrian rocks, and also sections showing the relative position, thickness, and the variations in the character of sedimentation from the south to the north as the formations pass to the north into Tennessee.

ALABAMA.

Our knowledge of the Cambrian rocks of Alabama is largely obtained from the Report of Progress for 1875. The nomenclature adopted for the fossiliferous sedimentary rocks up to the base of the Knox dolomite, by Prof. Safford, in Tennessee, is followed by Prof. E. A. Smith in this report. To the Primordial or Cambrian series he assigns the Acadian epoch, or the conglomerates and slates corresponding to the typical Ocoee section in Tennessee. To the Potsdam epoch he confines the Chilhowee sandstone of the Tennessee section. The Knox sandstone and Knox shales are referred to the Canadian period. The term "Calciferous sandstone" is used as the equivalent of Knox sandstone, and "Quebec shales" of the Knox shales. The section of the Acadian slates and conglomerates in Talladega County is considered by Prof. Smith typical of this series in Alabama.[1] The description is as follows:

> The western border of the Metamorphic rocks in Alabama is formed by a belt of slates and conglomerates, semi-metamorphic in aspect, and of varying width, but perhaps of an average width of six miles. These rocks, which in every respect seem to be the exact equivalents of Prof. Safford's Ocoee Slates and Conglomerates, are referred like them to the Acadian epoch.[2]

The stratigraphic succession of the beds is not well determined. There is a belt of greenish talcoid, or hydro-mica slate, and a series of conglomerates which are sometimes a slaty, arenaceous rock, but often

[1] Report of Progress of the Geological Survey of Alabama for 1875. Montgomery, 1876, pp. 13–17.
[2] Op. cit., p. 127.

quite massive, and made up of lumps of pebbles of opalescent quartz and opaque white feldspar, held in a matrix of greenish talcoid matter.

Of the second division, or the Potsdam, it is said:

Next in ascending order, to the slates and conglomerates of the preceding group, comes a series of sandstones which form the most conspicuous mountains outside the Metamorphic and Acadian areas. The direct superposition of this sandstone upon the slates of the Acadian age, I have not seen in Alabama, unless on the eastern edge of that belt, the prominent sandstone or quartzite ridge be, as seems quite probable, metamorphosed Potsdam sandstone. In the disturbed region of the Kahatchee Hills, also, half metamorphosed slates are seen, some of which may belong to the Acadian epoch, whilst others are evidently altered Knox shales.

Fine-grained conglomerates, heavy-bedded sandstones, and sandy shales make up the great mass of the rocks of this formation. I have noticed, also, occasionally, masses of a brownish porous chert, which, from its association with the sandstones, seems to be of the same age.

In general, the rocks of this formation are heavy bedded, almost massive, and the higher crests of the Potsdam Mountains are usually covered with huge blocks of sandstone and fine-grained conglomerate. In the lower parts of these ranges, sandy shales are the prevailing rocks. * * * The most characteristic markings of the rocks of this formation are the sandy rods, caused by the filling in with sand of the burrows of a marine worm, *Scolithus linearis*. Upon the bedding planes of the sandstones, small rounded depressions or dots mark the cross-sections of these Scolithus burrows. As yet I have found no other marks of organic origin in strata of this horizon. * * *

The nature of the rocks of this group, conglomerates, sandstones, and sandy shales, the fossil markings, principally the burrows of marine worms, etc., all point to a seashore origin.[1]

From the preceding descriptions, the equivalency of the Chilhowee sandstone and quartzite with that of Alabama is extremely probable, if not certain.

Of the succeeding formation, the Knox sandstone, the following description is given:

The rocks of this group succeed next, in ascending order, the Potsdam sandstone, and they are often, no doubt, found resting directly upon that rock. I have not, however, often seen them in this position; but much oftener just on the southeast side of a fault by which they have been raised to the level of a much higher formation. This sandstone is more generally associated with the shales of the next higher group, and these with dolomite, so that three groups are usually closely associated *geographically* as well as *lithologically*.

A calcareous sandstone, sometimes thick, sometimes thin bedded, is the characteristic Knox sandstone.

It is associated with hard calcareous shales much like the shales of the next higher division. The bedding planes of the sandstone commonly show ripple marks and irregular raised markings, which are commonly supposed to be fucoidal impressions. The bedding planes are also frequently smooth and shining as if polished. Green grains of glauconitic mineral are usually to be seen upon a fresh fracture of the sandstone; upon weathered surfaces the brown color of hydrated ferric oxide is often the result of the decomposition of this mineral. The colors of the Knox sandstone are pleasing to the eye, and are gray, greenish brown, buff, chestnut colored, etc. Beds of dolomite, impure and cherty, are found in the upper part of this formation; two such calcareous beds were noticed in the exposure of Knox sandstone at the Jackson shoals and also at Helena. * * *

[1] Op. cit., p. 13-15.

It [Knox sandstone] would naturally be looked for overlying directly the Potsdam sandstone of the mountains enumerated in a previous section; but it is not always easy to distinguish it; since, however, these ridges of Potsdam sandstone have a well defined belt of Knox shales on their eastern and southeastern flanks, the Knox sandstone, probably in most cases, intervenes between the two.[1]

It will be noticed in the description given of the Knox sandstone that its direct superposition upon the massive "Potsdam" sandstone has not been observed. I think that as in Tennessee the Knox sandstone may be, in part, the equivalent of the sandstone referred to the Potsdam or the Chilhowee sandstone. It is probably the accumulation of sand and shale deposited while the sediments of the more massive sandstones were accumulating nearer the coast line.

The Knox shales rest conformably upon the Knox sandstone series and correspond in their description closely with the Knox shales of Tennessee. Of these beds Prof. Smith says:

The characteristic rocks of this subdivision of the Knox group are calcareous shales of bright and agreeable colors, usually gray, buff, greenish, brown, chestnut colored, and red. The shales are tolerably soft, and in some portions in weathering, break up into small angular pieces resembling shoe pegs. Strata of dark blue limestone, sometimes banded with argillaceous layers, are found, especially in the upper part of this division. The weathering of such limestones brings into relief the bands or stripes of argillaceous matter, and the limestone appears very distinctly banded. Where these impurities are not so regularly disposed in layers, but in patches, the prominence given to them by the weathering away of the limestone gives them a striking resemblance to half-exposed fossils.

In some places layers of dark colored oolitic limestone have been observed, one of the best localities of this peculiar rock being at the foot of the mountain at Alpine Station in Talladega County.

In the upper part of the division blue limestone layers become more frequent, and the transition into the overlying Dolomite is so gradual that a line between them lithologically is hard to draw.[2]

The only instance mentioned to indicate the relations of the so-called Potsdam sandstone to the Knox shales is in the following paragraph:

Between the Ladiga Mountain and the hills of Acadian slate in Calhoun County, there are numerous small ridges of Potsdam sandstone, on the flanks of which the Knox shales seem never to be wanting.[3]

No fossiliferous strata were observed in this division.

The distribution of the Cambrian rocks of Alabama is shown on a map accompanying Prof. E. A. Smith's outline of the geology, published in 1878. On this map the geographic distribution of both the Cambrian and Lower Ordovician rocks is delineated under one color called the Silurian. It includes all the formations from the Clinton down to the Acadian. Of these formations the Cambrian includes, at the summit, the Quebec or Knox shale and Knox dolomite, or at least the lower portion of it, and subjacent to this the Calciferous or Knox sandstone, beneath which the Potsdam and Acadian are placed, the latter forming the base of the Paleozoic series.[4]

[1] Op. cit., pp. 17, 18. [2] Op. cit., p. 19. [3] Op. cit., p. 20.
[4] Outline of the geology of Alabama. Berney's Handbook of Alabama, 1878, p. 139.

In a report on the geology of the Cahaba Coal Field Prof. Eugene A. Smith describes the Cambrian rocks as they occur in the Coosa Valley of northeastern Alabama. The maximum thickness given is 10,000 feet in the eastern part of the Coosa Valley. The subdivisions of the Cambrian recognized are, in ascending order, as follows: "The Coosa shales, the Choccolocco or Montevallo shales, and, interbedded with the last named, the Weisner quartzite."[1]

The Coosa shales are described as thin-bedded limestones with clay seams at the base, and pass above into the Montevallo shales, which form a considerable thickness of sandy shales of a great variety of colors, such as olive, green, brown, chocolate, yellowish, etc. In the upper part of the Montevallo shales beds of blue limestone and gray dolomite occur which are difficult to distinguish from similar rocks occurring in the superjacent dolomite series. Lenticular masses of quartzite many hundreds of feet in thickness occur in the Montevallo shales. This quartzite is named the Weisner quartzite from its typical locality at Weisner Mountain, east of Jacksonville, and is correlated with the Chilhowee formation of Prof. Safford in Tennessee.[2]

From our present knowledge of the formations referred to the Cambrian in Alabama it appears that they are the continuation of those referred to the same group in Georgia and Tennessee, though varying somewhat in the local details of sedimentation, thickness of beds, and lithologic characters.

The section of Mr. C. Willard Hayes, described under Georgia, embraces much of the Cambrian strata that passes into Alabama, and should be referred to in this connection. (Ante, p. 304.)

RÉSUMÉ.

For a distance of over 1,200 miles the pre-Cambrian lands formed the eastern boundary of this province during the deposition of the sediments of Cambrian time. From below Montreal to the foot of Lake Champlain and thence southward to the crossing of the Hudson, below Poughkeepsie, New York, and on across New Jersey, Pennsylvania, Virginia, Tennessee, and into Georgia and Alabama, the rocks of this pre-Cambrian land form an almost continuous outcrop at the present day. The Cambrian rocks extend 400 miles farther to the northeast from Quebec to the northern portion of the peninsula of Gaspé; but there is now an interval of over 200 miles between the Archean ridges of eastern Quebec and the long, narrow Archean axis of the Gaspé peninsula. The exposures of the Cambrian on the coast of Labrador, opposite the Straits of Belle Isle, and those of the west shore of Newfoundland, have been included in the Atlantic Coast Province, but they are quite as much a

[1] Geological structure and description of the valley region adjacent to the Cahaba Coal Field. Geol. Survey of Alabama. Report on the Cahaba Coal Field, pt. II, 1890, p. 148, (issued January, 1891).

[2] Op. cit., pp. 148, 149.

part of the Appalachian Province by fauna and physical character and are considered as a connecting link between the two provinces. The Labrador deposits are on the north shore of the Cambrian sea, but those of the west shore of Newfoundland are, in physical character and organic remains, the practical continuation of the sediments of the eastern side of the Appalachian Province. If this correlation be made, the pre-Cambrian shore line is carried 400 miles farther to the northeast and thence to the Straits of Belle Isle, giving a nearly direct line of over 2,000 miles that may be included in the Appalachian Province with its Canadian extension. Along such a great extent of coast line one expects to find evidences of varying sedimentation, both in character and amount; and an examination of the various geological sections of Newfoundland, the river St. Lawrence, Vermont, New York, and south along the Appalachian range to Alabama, shows the most marked variation, both on the strike of the strata and in proceeding westward from the ancient shore line.

On the Labrador coast the rocks are sandstones followed by more or less impure limestone. On the western shore of Newfoundland, over 1,000 feet of alternating limestones, shales, and quartzites rest conformably upon 600 feet or more of slates. For 375 miles along the south shore of the St. Lawrence, from Cape Rosier of Gaspé to the vicinity of Quebec, the strata referred to the Cambrian consist, according to Mr. James Richardson, of quartzite, with intercalated beds of conglomerate holding limestone pebbles, the whole forming a series 600 feet in thickness. This is superjacent to 700 feet of gray sandstone, also carrying conglomerate, while beneath this a limestone, with conglomerates and bedded sandstones towards the lower portion of the section, extends down some 700 feet more, giving over 2,000 feet as the entire thickness of the section. Owing to the absence of paleontologic data there is some uncertainty in referring all of this series to the Cambrian. In some of the pebbles in the conglomerates of the upper portion a number of species of the Olenellus fauna were found; but no one of the three great divisions of the Cambrian has been distinctly recognized.

In the vicinity of Quebec the stratigraphic succession from below upward consists of a succession of black, green, and gray shales, with hard and heavy bands of green, sometimes yellowish white, quartzose sandstones. This is succeeded by greenish, grayish, and blackish, with occasionally dark reddish or purplish tinted shales, with a band of hard grayish sandstone. Above the latter bright red shales, with thin greenish or grayish bands, which in places are often calcareous, extend up through red, greenish gray, and black shales with interstratified masses, often lenticular, of greenish and grayish Sillery sandstone. In the upper part of this last series *Obolella pretiosa* occurs. A thickness of from 5,000 to 6,000 feet is estimated for the Cambrian series, beneath the graptolitic shales of Point Levis.

It will be noted of this section that the limestones of western New-

foundland and the lower portion of the south shore of the St. Lawrence are absent, and that the section is composed almost entirely of arenaceous and argillaceous sediments. A limestone conglomerate, near the upper portion of the Sillery, contains bowlders carrying the Olenellus fauna, and the Upper Cambrian fauna occurs in the basal conglomerates of the Point Levis, graptolitic, Lower Silurian (Ordovician) shales. These bowlders appear to have been derived from a limestone series similar to that now found in Labrador and Newfoundland.

The strata referred to the Cambrian, on the western side of the Sutton Mountain anticlinal or the belt extending southwesterly from Quebec to the Vermont boundary, consist of more or less of the Sillery series, as found in the vicinity of Quebec; and, according to Drs. Selwyn and Ells, of a subjacent series of hard quartzite rocks interstratified with mica schist and black slate. The volcanic series, referred to the Cambrian in this region, indicates that during earlier Cambrian time the volcanic products were deposited contemporaneously with the included sandstones and slates, thus giving a phase of sedimentation not known elsewhere in the Cambrian of the Appalachian province. For this reason and from the fact that there is not any paleontologic evidence of the age of this volcanic series I am inclined to think that it may belong to some pre-Cambrian terrane.

Entering the northern end of the valley, between the Green Mountains and the Adirondacks, a sudden change occurs in the sedimentation. At the base, the Olenellus fauna ranges through 1,000 feet of magnesian limestone, and for 250 feet higher up in arenaceo-argillaceous shales. More or less arenaceous matter is associated with the limestones, and, about 2,000 feet above, a great lenticular mass of limestone occurs in the argillaceous shales, in which a fauna of Upper Cambrian aspect is found. At other localities this fauna occurs in the shales themselves and in a brecciated limestone at the same relative horizon. As far as known the upper portion of the Cambrian is formed of the shales. Proceeding southward and nearer the old coast line in Addison County, Vermont, the limestone series is found to graduate into the Granular Quartzite or the beach sand. From this point this shore deposit is traced without interruption to the Massachusetts boundary; and then, with more or less interruption, to the Hudson River below Poughkeepsie, New York. It is taken up again in New Jersey, and thence may be followed, with some interruption, across Pennsylvania to Maryland, whence it extends as an almost continuous formation across Virginia into Eastern Tennessee, and thence, with some interruption, into Georgia and Alabama. On all this long line it forms the basal member of the Cambrian; and wherever fossils have been found in it they belong to the Olenellus or Lower Cambrian fauna.

The offshore, or deeper water deposits, are represented by finer-grained sandstones, shales, slates, and limestones. In southern Ver-

mont they form the roofing-slate belt that passes into New York, where the section comprises some 12,000 feet of shales, slates, and inter-

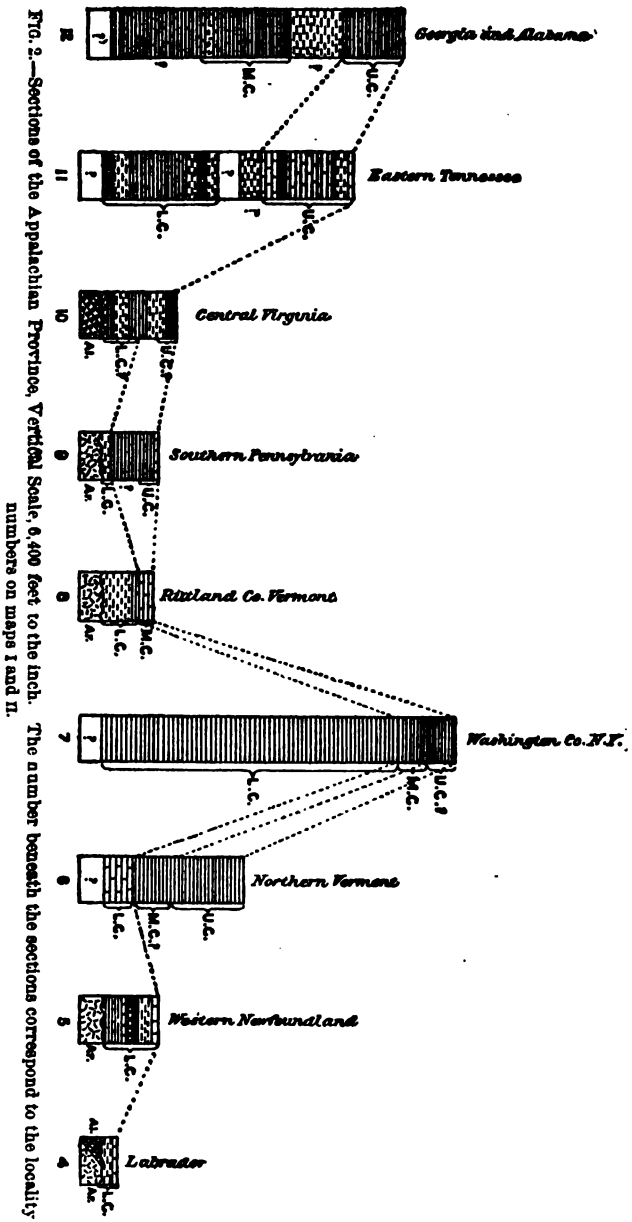


FIG. 2.—Sections of the Appalachian Province, Vertical Scale, 6,400 feet to the inch. The number beneath the sections correspond to the locality numbers on maps I and II.

bedded sandstones, with more or less calcareous matter, either as brec. ciated conglomerate or as thin-bedded, intercalated limestones. These extend, with some change in their character and regularity of exposure, to the Hudson River in Dutchess County. Near Stissingville, in this

county, the basal sandstone rests upon the pre-Cambrian and contains the Olenellus fauna. A few remains of the latter have also been found in the immediate superjacent limestone. The Middle Cambrian and Upper Cambrian faunas occur in bedded limestones As the quartzite exposed on the eastern side of the limestones of the "Marble Belt" represents but a very small portion of the great series of shales, slates, etc., of the Cambrian on the western side of the "Marble Belt," it is probable that the lower portion of the limestone is of Cambrian age, the same as in Dutchess County. This observation also applies to the basal limestone in New Jersey and Pennsylvania, where there is very little thickness of shales between the basal quartzites and the limestone.[1]

In central Virginia the lower 1,000 feet of the section is composed of an alternation of shales and sandstones, while the upper 1,400 feet is nearly all shales and slates, capped at the top by a rough siliceous limestone.

In Tennessee the quartzite is developed to a great thickness. The quartzite is of Lower Cambrian age, and the Knox series of shales are characterized in their upper portion by the Upper Cambrian fauna, which passes above into the base of the great limestone series. As far as known, the conditions in the sedimentation of the Alabama and Georgia sections are very much like those of Tennessee.

Briefly summarized, the sediments along the southern portion of the coast line are sandstones followed by shales and limestones. More or less variation occurs, but, as a whole, the change is gradual as we follow the coast line to the north. In central Virginia, 300 miles to the northeast, the argillaceous deposits are more abundant in the lower portion, and they form the greater part of the upper series to the base of the limestone.

From Virginia northward across Maryland, Pennsylvania, and New Jersey, and into New York, the argillaceous material accumulated in relatively small proportion to the arenaceous beneath and the calcareous above. How much of the latter is to be referred to the Cambrian, is yet undetermined. Our knowledge of the series in Pennsylvania and New Jersey is too limited to make an accurate comparison with other sections.

In western Massachusetts and Vermont and eastern New York there are immediate coast-line deposits and also those of deeper water. Along the coast line there was a great accumulation of sand, followed by some argillaceous and then calcareous mud. Farther to the west the argillaceous material predominates and the arenaceous and calcareous forms but a slight proportion of the great thickness of sediment. To the north these conditions remain until, in northern Vermont, the calcareous matter predominates in the lower portion of the

[1] The announcement was made at the December meeting of the Geological Society of America at Washington that the Olenellus fauna had been found in the quartzite in New Jersey, and Cambrian fossils in the limestones above the quartzite in New Jersey and at Rutland, Vermont.

section, and the upper portion is almost entirely argillaceous. In the vicinity of Quebec, sandstones and shales make up the section, and along the Lower St. Lawrence, shales, sandstones, and limestones.

As a whole, the Appalachian Province is one of varied sedimentation, and, from the character of the sediments and determined fossils now found in them, they were largely accumulated along a gradually sinking coast line. The northern and western shore line exhibits only the contact of the sandstones of the Upper Cambrian that overlap upon the pre-Cambrian rocks. Erosion has removed them to a large extent, and south of the Adirondacks the western coast line is unknown. (Fig. 2.)

ROCKY MOUNTAIN PROVINCE.

For the purpose of description the area of Cambrian rocks in the Rocky Mountain Province includes the Cambrian outcrops of northern and western Utah, Nevada, eastern Idaho, the Gallatin River district of Montana, and the Canadian extension.

UTAH AND NEVADA.

The Cambrian rocks of Utah and Nevada are considered together, owing to their having a common base in the presence of the Olenellus zone, the strata of which rests conformably upon a great series of siliceous and arenaceous shales and sandstones, and massive quartzites. In Nevada the section is much more complete and reaches a far greater development both in amount of sedimentation and the presence of organic remains. The section studied by Messrs. Hague and Walcott in the Eureka district may be considered typical of the Cambrian rocks of central Nevada. It embraces five formations, all of which are described by Mr. Arnold Hague in the abstract of his report on the Geology of the Eureka district.[1]

The Prospect Mountain quartzite that lies at the base of the series has a thickness of 1,500 feet on Prospect Peak. It is distinctly bedded and comformably subjacent to a band of arenaceous shale, in which the Olenellus fauna occurs. It is referred to the Cambrian by Mr. Hague, and I am now of the opinion that this should be done, although I have held the view that the Olenellus zone should be considered the base of the Cambrian, and the Prospect Mountain quartzite I tentatively referred to an Algonkian formation. The subjacent band of arenaceous shale is mentioned by Mr. Hague in his report of 1881,[2] but not in the more complete description of 1882. In the review of the Eureka section by Mr. C. D. Walcott in 1886 this formation is spoken of as follows:

> At the summit of 1 the quartzite becomes more thinly bedded and passes into an arenaceous shale which is more or less calcareous and, in its extension northward, is replaced by limestone. This belt of shale and limestone is from 100 to 200 feet in thickness and carries numerous fragments of fossils, among which we have determined

[1] U. S. Geol. Surv., 3d annual report, 1881-'82, 1883, pp. 254-259.

[2] Report (on work in Eureka District). U. S. Geol. Surv., 2d Ann. Rep., 1880-'81, p. 29, 1882.

six species, viz, *Kutorgina prospectensis*, *Scenella conula*, *Olenoides quadriceps*, *Olenellus gilberti*, *O. iddingsi*, *Anomocare parvum*, and *Ptychoparia* sp.?[1]

The second formation is the Prospect Mountain limestone. This is a massive limestone crystalline and granular in texture.

Interstratified in the limestone are irregular beds of shale, lenticular or wedge-shaped bodies, varying greatly in width. Indeed they form a characteristic feature in the limestone, which passes readily from massive to shaly beds. Two of the shale bands are quite prominent to the north, but are lost to the southward. The thickness of the beds may be taken at 3,050 feet.[2]

Formation No. 1, the arenaceous shale, between the quartzite and the limestone on Prospect Peak, is more or less a local formation, but it is apparently the zone of Olenellus, and the limestones above are not known to be characterized either by Olenellus or the typical forms of that fauna. Five hundred feet above the base of the Prospect Mountain limestone there occurs in a band of shale *Scenella conula*, *Agnostus interstrictus? Olenoides quadriceps*, *Ptychoparia prospectensis*. All but the last are closely related to species from the upper beds of the Georgia horizon, in either Vermont or Canada. One other species, *Stenotheca elongata*, which is found associated with *Olenellus thompsoni*, *Protypus senectus*, etc., at L'Anse au Loup, is found 2,000 feet higher up in the limestone. Another species, *Olenoides spinosus*, is found in association with species characteristic of a lower horizon than the typical Potsdam of Eureka, at Pioche, Nevada."[3]

Within a short distance of the summit of this limestone the fauna has the general facies of that of the upper Cambrian or Potsdam horizon; still as a whole it occupies the position of the middle Cambrian fauna as the faunas are now classified. That it sustains this view was pointed out by Dr. W. C. Brögger, in his admirable paper on the "Age of the Olenellus zone in North America."[4] He compares the fauna of the Prospect Mountain limestone with that of the Paradoxides zone of Europe and concludes that with the exception of the lowest part of the Olenellus zone it must correspond most nearly to the middle and upper part of the Paradoxides deposits of Scandinavia. His conclusions are based almost entirely upon the presence of the various species of the genus Agnostus. From the results of my studies since 1886, I am prepared to accept this view of Dr Brögger's and to consider the Prospect Mountain limestone as representing the Middle Cambrian or Paradoxides zone of the Atlantic Coast Province. A list of species published in 1886 is as follows:[5]

---

[1] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey. Bull. No. 30, 1886, pp. 30, 32.

[2] Hague, Arnold. Abstract of Report on Geology of the Eureka District, Nevada. U. S. Geol. Surv., 3d annual report, 1881-'82, 1883, p. 255.

[3] Second Contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey, Bull. No. 30, 1886, p. 32.

[4] Om alderen af Olenellus zonen i Nordamerica. (On the age of the Olenellus zone in North America.) Aftryk ur Geol. Fören. i Stockh. Förhan, No. 101, Bd. 8, 1886, pp. 182–213.

[5] U. S. Geol. Surv., Bull. No. 30, p. 32.

Obolella (like O. pretiosa).
Lingula manticula.
Kutorgina whitfieldi.
Orthis eurekensis.
Stenotheca elongata.
Agnostus communis.
bidens.
neon.
richmondensis.
Protypus senectus.
expansus.
Dicellocephalus ? nasutus.
Ptychoparia oweni.
haguei.
occidentalis.
dissimilis.
Olenoides spinosus.

Of the succeeding formation, or the Secret Cañon shale, Mr. Hague says:

The Prospect Mountain limestone passes, by gradual transition, from shaly limestone into brown and yellow argillaceous shales. * * * In their broadest development they measure 1,600 feet, although in places where they are encroached upon by the Hamburg limestone they occur considerably thinner.[1]

Only a few scattering fossils are found in the lower portion of the Secret Cañon shale, but near the summit of the fauna is large and characteristic. It includes, according to Mr. C. D. Walcott, the following:[2]

Protospongia fenestrata.
Lingulepis maera.
minuta.
Lingula ? manticula.
Iphidea depressa.
Acrotreta gemma.
Kutorgina minutissima.
Hyolithes primordialis.
Agnostus communis.
bidens.
neon.
seclusus.
Dicellocephalus ? nasutus.
Dicellocephalus richmondensis.
Ptychoparia pernasuta.
laticeps.
bella.
linnarssoni.
oweni.
haguei.
similis.
unisulcata.
læviceps.
Chariocephalus tumifrons.
Ogygia ? problematica.

Of the species in this list *Dikelocephalus ? nasutus*, and *D. richmondensis* do not belong to the genus Dikelocephalus and the form referred to *Ogygia ? problematica* represents an undefined genus. As a whole, as suggested by Dr. Brögger, this horizon may possibly be referred to the Paradoxides zone.

Number 4 of the section, or the Hamburg limestone, is a dark gray and granular limestone; surface, weathering rough and ragged; only slight traces of bedding. Very few traces of fossils were found in the entire 1,200 feet of rocks referred to this formation.

No. 5, or the Hamburg shale, resembles the Secret Cañon shale except that it is by no means as uniform in composition, showing very rapid changes in conditions of deposition and becoming more or less arenaceous and calcareous throughout its development as well as in its lateral extension. Throughout its entire thickness of 350 feet fossils are more

[1] Abstract of Report on Geology of the Eureka District, Nevada. U. S. Geol. Surv., 3d Annual Report, 1881-1882, 1883, p. 255.
[2] Ibid., p. 32.

or less abundant, but especially so near the summit where there were obtained the following:

Lingulepis mæra.
  minuta.
Lingula? manticula.
Obolella discoidea.
Acrotreta gemma.
Kutorgina minutissima.
Agnostus communis.
  bidens.
  neon.
  prolongus.
  tumidosus.
  tumifrons.
Dicellocephalus? nasutus.
Dicellocephalus angustifrons.
  marica.
  bilobus.
  osceola.
Ptychoparia affinis.
  oweni.
  haguei.
  granulosa.
  simulator.
  unisulcata.
  breviceps.
Arethusina americana.
Ptychaspis minuta.

"Three of these species, *Hyolithes primordialis, Dikelocephalus osceola* and *Ptychaspis minuta*, are identical with forms from the Potsdam sandstone of Wisconsin."[1] As a whole the fauna is of the general facies of that of the Potsdam zone of New York and the Mississippi Valley. This is found in the Hamburg shale, but in the overlying Pogonip limestone there is an assemblage of species that combine both Cambrian and Lower Silurian (Ordovician) types. A short distance above, the fauna is comparable to that of the Calciferous and Chazy groups of the New York section.

The transition from the Cambrian to the Silurian [Ordovician] fauna is very gradual, and such as would occur where there was no marked physical disturbance to influence the faunal change resulting from the natural dying out and development of species or the influx of new species from other areas.

Of the species occurring below the passage beds three are identical with species occurring in the Potsdam sandstone of Wisconsin, viz: *Hyolithes primordialis, Dicellocephalus osceola,* and *Ptychaspis minuta;* one, with *Acrotreta gemma* of the Calciferous formation of Newfoundland; and *Ptychoparia oweni* is a common species of the Potsdam horizon in Montana and Dakota. These specific identifications and the great development of species of the genera Agnostus, Dicellocephalus, and Ptychoparia in the middle and upper portion of the Cambrian section, furnish abundant evidence upon which to correlate the fauna and the geologic horizon at which it occurs with the Potsdam fauna and formation, as was done by Messrs. Hall and Whitfield (Geol. Expl. Fortieth Par., vol. 4, 1877, p. 199). Of the Potsdam fauna eleven genera and fifteen species continue on into the passage fauna, viz: (species of the Potsdam fauna are printed in italics): *Lingulepis mæra, L. minuta, Lingula? manticula,* Discina (sp. undt.), *Acrotreta gemma,* Schizambon typicalis, Obolella ambigua, *O. discoidea, Leptæna melita,* Orthis hamburgensis, O. testudinaria, Triplesia calcifera, Tellinomya? hamburgensis, *Agnostus communis, A. bidens, A. neon,* Dicellocephalus finalis, D. inexpectans, Ptychoparia? annectans, *Ptychoparia affinis, P. granulosus, P. haguei, P. oweni, P. unisulcatus, Arethusina americana,* Amphion (sp. undt.) Barrandia maccoyi, Illænurus eurekensis, Asaphus caribouensis.

In the next superior grouping, about midway of the Pogonip group, all the middle Cambrian genera, with the exception of Orthis and Illænurus, have disappeared, and higher up the genera Receptaculites, Chætetes, Pleurotomaria, Maclurea, Cyphasis, Bathyurus, and Asaphus carry the fauna up to the summit of the formation where the genera Receptaculites, Ptilodictya, Chætetes, Strophomena, Orthis, Tellinomya,

[1] Op. cit., p. 33.

Modiolopsis, Maclurea, Crytolites, Orthoceras, Endoceras, Coleoprion, Leperditia, Beyrichia, Amphion, Ceraurus, and Asaphus give it a facies approaching that of the Lower Trenton and indicating a horizon that is considered to be in a measure the equivalent of that of the Chazy formation of New York and Canada. The fauna of the lower portion of the Pogonip group corresponds in the same manner to that of the Calciferous sand-rock of the same region. The large number of individuals of the species of Receptaculites, *R. mammillaris* especially, gives the fauna of the upper beds a character that this horizon has not hitherto had. This, united with several of the Trenton species, viz, *Orthis testudinaria*, *O. tricenaria*, *O. perveta*, *Tellinomya contracta*, two species of Modiolopsis allied to Trenton forms, and *Raphistoma nasoni*, strongly foreshadows the opening of the Trenton period.[1]

The section of the Highland Range, 125 miles south of the Eureka section, gives a greater variation of sedimentation in the lower portion and less in the upper as compared with the Eureka section. The Highland Range has a more abundant and more varied fauna in the lower 1,500 feet above the quartzite, while in the Eureka section the upper or Potsdam fauna is much larger than in the Highland section. In each instance a massive limestone has replaced a succession of limestones and shales. The Highland Range section measuring from the base is as follows:[2]

	Feet.
(1) Dark reddish brown quartzite, evenly bedded, and ripple-marked in some places	350
(2) Bluish gray limestone	35
Fossils: *Olenellus gilberti*.	
(3) Buff argillaceous and arenaceous shales, more or less solid near the base and laminated in the upper portions	80
Fossils: Annelid trails and fragments of Olenellus in the lower part. Higher up the heads of *Olenellus gilberti* and *O. iddingsi* occur in abundance.	
(4) Light-colored gray limestone and bluish black limestone	16
(5) Sandy, buff-colored shale	40
Fossils: Annelid trails, Cruziana sp.?	
(6) Dark bluish black limestone	46
(7) Finely laminated buff argillaceous shale	80
Fossils: *Hyolithes billingsi* and *Ptychoparia piochensis*.	
(8) Gray to bluish black compact limestone	18
(9) Buff arenaceous shales	64
(10) Compact cherty limestone	50
(11) Compact shaly sandstone in massive layers	40
(12) Hard siliceous gray limestone, almost quartz at base	12
(13) Yellow to buff, sandy shale	70
(14) Bluish black limestone	16
(15) Yellow to buff sandy shales	40
(16) Bluish black, hard, compact limestone	12
Fragments of fossils.	
(17) Shaly sandstone in massive layers	52
(18) Gray arenaceous limestone	2

[1] Walcott, C. D.: Paleontology of the Eureka District. U. S. Geol. Surv., Monograph, vol. 8, 1884, pp. 3, 4.

[2] Walcott, C. D.: Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Surv., Bull. No. 30, 1886, pp. 33, 34.

		Feet.	
(19)	(*a*) Buff, sandy shale	40	
	(*b*) Gray arenaceous limestone	30	
	(*c*) Sandy, calcareous shale	3	
			73
(20)	(*a*) Massive-bedded, bluish gray limestone. Fragments of fossils.	200	
	(*b*) Compact gray siliceous limestone, almost quartzite in some places	400	
	(*c*) Bluish black, evenly bedded limestone	6	
			606

Strike N. 30° W., dip. 10° E.

(21) Buff to pinkish argillaceous shale, with fossils, and a few interbedded layers of limestone from 3 to 15 inches thick 125

Fossils: *Eocystites ?? longidactylus, Lingulella ella, Kutorgina pannula, Hyolithes billingsi, Ptychoparia piochensis, Olenoides typicalis Bathyuriscus howelli*, and *B. producta*,

(22) Massive-bedded, siliceous limestone; weathering rough and broken into great belts, 200 to 300 feet thick, by bands of color in light-gray, dark-lead to bluish black; on some of the cliff faces the weathered surface is reddish 1,570

(23) Bluish black limestone in massive strata, that break up into shaly layers on exposure to the weather. The latter feature is less distinct 850 feet up, and the limestone becomes more siliceous, with occasional shaly beds 1,430

Fossils; near the summit specimens were found that are referred to *Ptychoparia minor*.

Quite a fauna occurs in 23, as found one mile farther south an the line of the section.

Summary of section.

	Feet.
1. Quartzite	350
2. Limestone and shales (argillaceous and arenaceous)	1,450
3. Massive limestones	3,000
Total	4,800

As in the Eureka section, the species of Olenellus have a very narrow range near the base of the limestone series above the quartzite.

The fauna found in No. 21 of the section materially strengthens the correlation of the fauna of the Prospect Mountain limestone and the Secret Cañon shale with that of the Paradoxides zone of the Atlantic Basin.

The fauna of the great limestone belt above 23 of the section is represented by only a few specimens on the line of the section. A mile south, however, on the strike of the strata a strongly marked Upper Cambrian (Potsdam) fauna occurs. The species identified are as follows:

Bellerophon antiquatus.	Dicellocephalus sp.?
Pleurotomaria, 3 undt. sp.	Ptychoparia (Euloma ?) dissimilis
Hyolithes, 3 n. sp.	P. sp.?
Dicellocephalus pepinensis.	Arethusina americana.
D. (type of D. minnesotensis).	Illænurus sp.?

Of this fauna two species are identical with those from the higher Potsdam fauna at Eureka, viz: *Ptychoparia* (*E.?*) *dissimilis* and *Arethusina americana*; and *Bellerophon antiquatus*, and *Dicellocephalus pepinensis* occur in the upper Potsdam of Wisconsin.

The presence of the Pleurotomaria-like shells and the species just mentioned correlates the fauna with that of the upper horizon of the Potsdam faunas of Wisconsin and Nevada.[1]

We have no details of the section of Silver Peak, Nevada, to which attention was called by Prof. J. D. Whitney. The fossils are from a limestone and silico-argillaceous shale and identical with species found elsewhere. The most noteworthy occurrence is that of *Archæocyathus* = *Spirocyathus atlanticus* and a large brachiopod like *Kutorgina cingulata*, both of which occur on the Labrador coast over 3,000 miles to the northeast on the opposite side of the continent. The abundant and peculiar type of sponge *Archæocyathus profundus* of the L'Anse au Loup locality is represented by the nearly identical species *Ethmophyllum whitneyi* of Silver Peak, and the tribolite *Olenellus gilberti* is scarcely distinguishable from *O. thompsoni*, as it occurs in L'Anse au Loup. The species now known from Silver Peak are:[2]

Spirocyathus atlanticus.	Kutorgina (like K. cingulata).
Archæocyathus undt. sp.	Hyolithes princeps.
Ethmophyllum whitneyi.	Olenellus gilberti.
Strephochetus ? sp. ?	

The Cambrian rocks of Utah, as determined by the presence of the Cambrian fauna, form a narrow horizon in the vast series of sediments of which they are a conformable portion. Messrs. Emmons and King refer the 12,000 feet of siliceous slates and quartzites of the Big Cottonwood section to the Cambrian. If we provisionally drew the basal line of the Cambrian at the base of the strata known to contain the Olenellus fauna, all but 250 feet of this section would be referred to the Algonkian, but from the known range of Olenellus in the stratigraphically equivalent series to the north in British Columbia, the view is no longer tenable. The upper portion of the section consists of 250 feet of hard silico-argillaceous shale, a little sandy in places. At the base a species of Cruziana was found, associated with *Olenellus gilberti*, and 100 feet higher in the section a band of shale afforded *Lingulella ella*, *Kutorgina pannula*, *Hyolithes billingsi*, *Leperditia argenta*, *Ptychoparia quadrans*, and *Bathyuriscus producta*. This list was published in 1886, along with Cruziana and *Olenellus gilberti*, as characterizing the shales at the summit of the great series of quartzites and slates. As in the Eureka and Highland Range sections, the Olenellus zone is confined to a very narrow belt just above the quartzite. The silico-argillaceous shales above occupy the position of the 4,650 feet of Prospect Mountain limestone and Secret Cañon shale of the Eureka section. The Hamburg limestone and Hamburg shale of the latter are absent in the Big Cottonwood section, causing an unconformity by nondeposition.[3] The section in the Oquirrh Range above Ophir City has a quartzite at the base with shales above it carrying *Lingulella ella*, *Olenellus gilberti*, and *Bathyuriscus producta*, as determined by the collections brought in

[1] Op. cit., pp. 35, 36. [2] Op. cit., p. 38. [3] Op. cit., p. 39.

by the Wheeler survey. It is probable, however, that as in the case of the Big Cottonwood section, *Olenellus gilberti* occurs at the base of the shale, and the other two species at a higher horizon. At Antelope Spring, in western Utah, there is a considerable development of the Middle Cambrian zone corresponding to No. 21 of the Highland Range section and a portion of the Prospect Mountain limestone of the Eureka section. The section at this locality as measured by Mr. G. K. Gilbert is as follows:[1]

	Feet.
1. Gray, massive limestone	200
2. Blue gray, calcareous shale; fossils (as corrected by C. D. W.); *Acrothele subsidua, Agnostus interstrictus, Olenoides nevadensis, Ptychoparia kingi, P. housensis, and Asaphiscus wheeleri*	200
3. Gray limestone, light and dark, chiefly massive	900
4. Vitreous sandstone, umber-brown on weathered face; base not seen	1,000
Total	2,300

No. 4 of this section corresponds to the basal quartzite of the Eureka and Highland Range section, and No. 3 with the Prospect Mountain limestone. No. 2 may correspond to the upper portion of the latter limestone or to the lower portion of the Secret Cañon shale of the Eureka district. There is not enough known of the Antelope Spring section to enable us to make any closer correlation.

A comparison of the sections of Utah with those of Nevada shows that in the former the earlier conditions of sedimentation were apparently the same from the base of the Wasatch Mountains westward into central Nevada. But during the deposition of the Middle and Upper Cambrian rocks the immediate vicinity of the Wasatch was an area of minimum deposition, while that of central Nevada was one of maximum deposition of sediments. What the conditions were during the deposition of late Middle and Upper Cambrian time in the Wasatch area are unknown. The appearance of the rocks indicate a shallow sea with very little deposition of sediment.

IDAHO.

What is known of the Cambrian rocks of Idaho is obtained from the writings of Messrs. Bradley and Peale. The report of the former is more that of an explorer who, passing over the ground, made such geologic notes as time permitted. In the vicinity of Malade City, in southeastern Idaho, he discovered in a limestone resting on a quartzite, fifteen species of trilobites of the genera Conocoryphe, Bathyurus, Dikelocephalus, Agnostus, etc., five brachiopods, two gasteropods, and one pteropod. He referred this fauna to the Quebec group, and the

[1] Report on the geology of portions of Nevada, Utah, California, and Arizona examined in the years 1871 and 1872. Report on Geog. and Geol. Expl. and Survey west of the 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 167.

quartzitic sandstone beneath is spoken of as occupying the relative position of the Potsdam, although he subsequently refers to it as a part of the true Quebec.[1] Mr. F. B. Meek agreed with Prof. Bradley that the fauna belonged to the Quebec horizon; and he[2] described *Bathyurellus* (*Asaphiscus*) *bradleyi* and *Asaphus* (*Megalaspis?*) *goniocercus*. The latter species probably comes from the upper portion of the limestone referred to the Quebec group by Prof. Bradley.

From the data obtained by Dr. A. C. Peale of the Gallatin River Cambrian, and our more accurate knowledge of the fauna of the Quebec group, the faunas occurring in the lower portion of the limestone at Malade City are referred to the Upper Cambrian, and those from the upper portion of the limestone to a portion of the Lower Silurian (Ordovician). In this connection reference should be made by the reader to Prof. Orestes St. John's work upon the same beds in Wyoming.

Near the south end of Portneuf Range, north of Malade City, Dr. A. C. Peale measured the following section:[3]

Top.

	Feet.
1. Blue limestone	130
2. Laminated blue limestones, with Conocoryphe, Dikellocephalus, Obolella, and two species of Bathyurus	315
3. Bluish gray limestones	
4. Laminated limestones, with bands of greenish shales in the upper portion. The limestones are separated by shaly layers. The limestones are fossiliferous at the base, containing quantities of a trilobite like Conocoryphe. The limestone resembles an oolite, but the structure is probably due to the presence of some peculiar organic remains. Fragments of Discina were seen	120
5. Rather massive limestones	
6. Laminated blue limestones, in bands of from 1 to 2 inches thickness, the surfaces of which are yellow-stained.	
7. Rather massive limestones	118
8. Green shales or slates, 15 feet	
9. Bluish gray limestone	
10. Bluish limestones, with bands of shales	155
11. Massive blue limestones. The dip here appears to be about 40°	100
12. Laminated limestones with interlaminated green shales	70
13. Greenish sandstones and shales, passing below into silvery gray slates	210
14. Slates and shales with a band of limestone about the middle	185
15. Blue limestones with irregular structure. The strike is about south 5° east, and beyond the station it appears to curve to the south; dip is 60°	70
16. Rusty yellow quartzite	150
17. Gray and yellowish quartzites	450
18. Greenish gray slates	180
19. Rusty yellow quartzite, somewhat conglomeritic and containing a considerable percentage of iron	130
20. Rusty quartzites, about	600
21. White quartzites	500 to 600
22. Pink and white quartzites	
23. Red slates, thickness not taken	
Total	3,483 to 3,583

[1] Report of Frank H. Bradley, geologist of the Snake River division. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, p. 201.

[2] Preliminary paleontological report; with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., embracing portions of Montana, Idaho, Wyoming, and Utah, 6th Ann. Rep., Ibid. 1873, pp. 480–485.

[3] Report on the geology of the Green River District. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, p. 568.

Below this last layer there are probably the limestones of the Red Rock Pass.

This section is one of considerable interest, from the fact of its having the Upper Cambrian fauna in the upper portion and an alternating series of limestones, shales, and quartzites below, which, from a comparison with the sections of western Utah and central Nevada, occupy the stratigraphic position of the Middle Cambrian. In their downward continuation, they may also include the Lower Cambrian zone. This is a question which is to be settled by future investigation.

In the adjoining Bannock range to the west, Dr. Peale studied a section of the series of quartzites and slates that apparently correspond to those of Nevada and Utah, occurring beneath the Lower Cambrian (Olenellus) zone. The section figured by Dr. Peale includes 5,710 feet of quartzites and slates, with a little interbedded limestone. He compares it with the section on the western side of the Wasatch range, referred to the Cambrian by Messrs. Emmons and Hague.[1] In his résumé of the formations, the Cambrian or Primordial is made to include the quartzites and slates that may be tentatively assigned to the Algonkian, or to the Cambrian, but preferably to the latter. To the Canadian Period there are referred 1,300 feet of interlaminated limestones and quartzites that occur above the quartzite and slate series now referred to the Cambrian. Dr. Peale states that west of Malade City the section gives 2,000 feet of strata placed in the Quebec series by Prof. Bradley.[2]

The northern end of the Port Neuf range was studied by Prof. Orestes St. John, in the vicinity of Mount Putnam. He there found the section to be formed of quartzites, chloritic schists, slates, and micaceous shales at the base, above which comes the dark red, finely laminated sandstone in thick beds. These he referred to the Potsdam with a query. In speaking of this section, Dr. Peale says he thinks Prof. St. John is inclined to refer the base of the section to the Huronian.[3]

With the information afforded by his own survey and that of Prof. St. John, Dr. Peale constructed the following table as embodying their knowledge of the Lower Paleozoic section of Idaho :[4]

[1] Op. cit., p. 570. [2] Op. cit., p. 614. [3] Op. cit., p. 615. [4] Op. cit., p. 615.

Silurian section.

Canadian.	Quebec.		Blue and gray limestones, with characteristic Quebec fossils.	1,000+ ft.	1,500 + ft.	Section No. 21, station 133.
	Calciferous?		Blue limestones, generally laminated, with alternations of greenish sandstones and shales and siliceous slates.	500 ft.		
Cambrian or Primordial.	Potsdam.	Cambrian quartzites.	Pink and white quartzites, conglomeritic at top, with thin layer of limestone at the base.	2,000 + ft.	7,060 + ft.	Section No. 22, station 77.
	Acadian?	Cambrian slates.	Olive-green and gray chloritic slates and indurated clay slates.	1,560 ft.		
			Silvery and steel-gray micaceous slates.	1,900 ft.		
			Dark quartzites with interlaminated slates.	1,600 ft.		
	Possibly Huronian?	Red quartzites and quartzitic sandstones, with conglomeritic and shaly layers.		350 ft.	1,250 ft.	Section No. 32, station 132.
		Limestones.				
		Very dark green chloritic schists, containing quartz and serpentine seams and interlaminated bands of metamorphosed argillaceous slates, and a band of pink quartzite 200 feet thick.		900 ft.		

In copying the table it has been reversed, so as to follow the natural order. As interpreted in the light of our present knowledge of the Cambrian rocks in the Rocky Mountains, the Quebec and Calciferous of this section are referred to the Upper Cambrian. Whether the rocks referred to the Potsdam and Acadian are of Cambrian age or not will remain undetermined until some paleontologic proof is obtained.

MONTANA.

As far as known, the Cambrian rocks of Montana are restricted to the southern portion of the State. Two areas are well defined, one about the northern end of the Big Horn range and the other within the area drained by the Gallatin and the Yellowstone Rivers.

The character of the strata forming the Cambrian about the Big Horn Mountains will be spoken of in connection with the extension of that range in Wyoming. The Gallatin section of the Cambrian includes 1,250 feet of strata, of which 835 feet are limestone, resting upon 415 feet of sandstone. Conformably subjacent to the latter, there are 5,000 feet of alternations of conglomeritic, micaceous sandstones, with bands of siliceous limestones and indurated clay shales, referred to the Algonkian by Dr. A. C. Peale.[1]

A more detailed manuscript section, that Dr. Peale kindly prepared at my request, is as follows:

Gallatin limestones 835 feet...	Pebbly limestones 145 feet. (fossils, *Leptæna melita*, *Ophileta sp.?* *Triplesia calcifera*, *Ptychoparia* sp.? *Ptychoparia* (*E.*) *affinis*). Dry Creek shales 30 feet. Mottled limestones 160 feet. (fossils, *Ptychoparia* sp.? *Hyolithes* sp.?) Obolella shales 280 feet. (fossils, *Obolella* sp.?) Trilobite limestones 120 feet. (fossils, *Lingulella* sp., *Acrotreta gemma*. *Kutorgina sculptilis*, *Agnostus bidens*. *Hyolithes gregaria*, *Olenoides serratus*. *Ptychoparia gallatinenses*. *Bathyuriscus? haydeni*).
Gallatin sandstones 415 feet...	Gallatin shales 290 feet. (fossils, *Lingulella* sp.? *Hyolithes* sp.? *Ptychoparia* sp.?) Gallatin quartzite 125 feet.

It is probable that the 5,000 feet of strata referred to the Algonkian in the published section will ultimately be referred to the Lower Cambrian as they occupy the stratigraphic position of the Bow River series to the north in British Columbia through the upper 3,000 feet of which the Olenellus fauna has been found to range.

The section near the mouth of the East Gallatin River was studied in detail by Dr. Peale in 1884, and two lithologically well defined groups determined and characterized as follows:

To the lower one, which was carefully searched, without success, for organic remains, the name of East Gallatin group has been provisionally applied. It is composed of a series of alternations of green and greenish gray micaceous sandstones and clay slates (almost argillites), with thin bands of laminated limestones; 2,300 feet of these beds were sectionalized in detail without any traces of fossils being found.

The sandstones are in heavy beds and present a somber appearance, weathering on exposed surfaces to steel-gray and almost black colors and frequently breaking into cubical blocks. The slates are blue, yellowish, olive-green, and at some places red. In the limestone a concretionary structure is frequently noticed. For the upper group, lying above a well defined pink quartzitic sandstone, we have retained the name Potsdam. Green and dark purplish red micaceous shales, mostly arenaceous, with occasional thin bands of limestone, make up this group, and many of the beds are highly fossiliferous. The collections have not been carefully studied yet, and we therefore simply refer to them in this general way at this time.[2]

[1] Report of Dr. A. C. Peale (on the Montana division of geology). U. S. Geol. Surv., 10th Ann. Rep., 1890, p. 131.

[2] Hayden, F. V.: Report Montana Division. U. S. Geol. Surv., 6th Ann. Rep., 1884–'85, 1885, p. 50.

The fauna collected in the Gallatin River section by Dr. Hayden in 1872 was studied by Mr. Meek, who recognized eighteen species. From the lowest division he identified the genera Cruziana, Lingulepis, or Lingula, Conocoryphe, Bathyurus, or Asaphus. From the third division he described *Bathyurus serratus*, *B.? haydeni*, *Conocoryphe* (*Conocephalites*) *gallatinensis*, *Iphidea subtilis*, and *Agnostus bidens*; and identified a species of *Conocoryphe*, *Hyolithes gregaria*, and *Acrotreta subconica*. From the second division the genera Acrotreta and Lingula are identified, and from the upper or first division Asaphus?, Bathyurus? Conocoryphe, and Lingulepis.[1] This fauna has the facies of the Upper Cambrian zone, although that of the fourth or lowest division may prove to belong to the Middle Cambrian. As a whole the Cambrian of the Gallatin region is formed of a sandstone at the base, above which occur limestones carrying a fauna characteristic of the upper portion of the group.

The presence of the Upper Cambrian on the southwestern side of the Little Belt Mountains and on the southern side of the Elk Range was proved by Messrs. Dana and Grinnell when they discovered fossils of this age. The section near Camp Baker, southwest of the Little Belt Mountains, is estimated as follows:[2]

Quartzite, 20 feet; variegated shales, mostly bright red, also green and blue, 150 feet; limestone in a double series of ledges, 80 feet; quartzite, reddish, slightly micaceous, then a series of colored slates, mostly green, followed by shales and thin beds of sandstones and limestones, in all probability 1,500 feet; still further conformable shales, 1,000 feet. These extend toward the north farther than we could follow them. It is enough to say that the total thickness of the conformable strata underlying the fossil-bearing limestone can not be less than 3,000 feet, and is probably much more.

The same authors state that they identified similar rocks at Moss Agate Springs, at the south extremity of the Elk Range of mountains. The strata there are red shales, quartzites, and limestones like those at Camp Baker, the limestones containing many fragments of trilobites. The fossils collected were studied by Prof. R. P. Whitfield, who described *Crepicephalus* (*Loganellus*) *montanensis* and *Arionellus tripunctatus*,[3] species that occur in the Upper Cambrian horizon, the former in the Black Hills and Big Horn Range, and the latter in central Texas.

From his observations at numerous points Dr. F. V. Hayden concluded that the outcrop of the sandstone referred by him to the Potsdam extended entirely around the Big Horn Mountain Range. Near the sources of Powder River he found a series of sandstones underlying the Carboniferous limestone, resting unconformably upon the schistose and clay slates of the Azoic series in very nearly the same manner as

[1] Preliminary paleontological report . . . with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., 6th Ann. Rep., 1873, pp. 463, 464.

[2] Geological report. Report of a geological reconnoissance from Carroll, Montana Terr., on the Upper Missouri to the Yellowstone Park and return, made in the summer of 1875, by Wm. Ludlow, 1876, p. 133.

[3] Descriptions of new species of fossils. Ibid. p. 141.

in the Black Hills. The Potsdam sandstone in this region is quite well developed, attaining a thickness of 200 feet, and exhibiting, as usual, various lithologic characters. Near the base, the rock is of a reddish flesh color, very compact, composed of an aggregation of quartz pebbles, varying in size from a minute grain of quartz to masses half an inch in diameter, cemented by siliceous matter. Above, the rock is in thin ferruginous layers, slightly calcareous but mostly siliceous, and with many small particles of mica. These thin layers are also charged with fossils, such as *Lingula antiqua*, *Obolella nana*, *Theca gregaria*, and *Arionellus? oweni*. Many of the slabs are covered with fucoidal markings and what appear to be tracks and trails of worms.[1]

CANADIAN EXTENSION.

Our knowledge of the Cambrian rocks of this region is mainly limited to the vicinity of the line of exploration across the Rocky Mountains in the vicinity of the Canadian Pacific Railway. They occur in western Alberta and eastern British Columbia, as is shown in the plates and sections accompanying Mr. R. G. McConnell's paper.[2] The geographic distribution and the localities mentioned by Mr. McConnell are represented on the map accompanying the report of the Geological Survey of Canada for 1882.

The Cambrian section, identified by fossils, includes the upper portion of the Bow River group and the lower part of the Castle Mountain group. The Bow River group forms the basal member of the section in the Bow River Valley and Cathedral Mountains. It consists mainly of a series of dark colored argillites, associated with some sandstones, quartzites, and conglomerates. The argillites are usually dark grayish in color, but become greenish and purplish in places; are very impure, and frequently grade into flaggy sandstones that are often slightly calcareous. The conglomerates of this series are characterized by pebbles of milky or semitransparent quartz, and by pieces, similar in size and fresh looking, of whitish feldspar, and the matrix contains an abundance of pale mica. These constituents have evidently been derived from some not far distant exposures of coarse granite or gneissic rock. The conglomerates characterize more especially the top of the formation, and occur in thick, massive looking bands, alternating with quartzites and shales. The quartzites, like the conglomerates, are mostly found in the upper part of the formation, and sometimes, as in Cathedral Mountains, replace the latter altogether. The only fossils detected in the Bow River series are specimens of *Olenellus gilberti*, found about 2,000 feet below the top of the formation and at the summit of Vermilion Pass.

[1] The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d ser., vol. 33, 1862, pp. 71, 72.

[2] Report on the Geological Structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, new ser., vol. 2, 1886–'87, pp. 24D–30D.

Attention was called to the resemblance of the strata of the Bow River series to those of the Big Cottonwood Cañon section of the Wasatch Mountains of Utah, by Dr. G. M. Dawson, in 1885. A comparison of the two leads to their correlation as equivalent formations, on the evidence of their lithologic characters and stratigraphic position and the fact that the Olenellus fauna occurs in the upper portion of each section. In his paper of 1889 Mr. R. G. McConnell[1] states that specimens of Paradoxides and other fossils were found at the junction of the Bow River and the superjacent Castle Mountain group. A collection made at this horizon was sent to me for examination, and I identified Olenellus sp. undt., *Protypus senectus*, and a species of Ptychoparia undistinguishable from *P. adamsi* of the Olenellus zone of Vermont. The occurrence of the Olenellus fauna at this horizon and of *Olenellus gilberti*, 3,000 feet lower in the section, corresponds to the great range of the fauna in the New York and Vermont sections.

The Castle Mountain group, in the Castle Mountain section, commences with a thin band of shaly limestone, above which come 1,500 feet of massive dolomites. These are subjacent to some yellowish, compact, impure dolomites, above which 300 feet of reddish shales occur subjacent to several hundred feet of shaly magnesian limestones. The Mount Stephen section shows about 5,000 feet of beds, consisting mainly of heavy dolomites, with shaly bands at intervals. One of these, occurring at the base of the formation and another about 2,000 feet higher up, are rich in trilobites.[2]

Reference has already been made to the fauna occurring at the base of Castle Mountain. From the next fossiliferous zone, 2,000 feet up in the section, the following species have been obtained:

Lingulella macconnelli.
Crania? columbiana.
Kutorgina prospectensis.
Acrotreta gemma, var. depressa.
Linnarssonia sagittalis.
Orthisina alberta.
Platyceras romingeri.
Hyolithellus micans.
Agnostus interstrictus.
Olenoides nevadensis.
Zacanthoides spinosus.
Ptychoparia cordilleræ.
Bathyuriscus howelli.
(K.) dawsoni.
Karlia stephenensis.
Ogygopsis klotzi.

Where the line between the Cambrian and the Lower Silurian (Ordovician) is to be drawn in the Castle Mountain group is still undetermined. The discovery of a specimen of *Ptychoparia oweni* in the débris washed down by the Cascade River from the Cascade Mountains indicates the presence of the Upper Cambrian fauna in this region, and it is not improbable that it will be found in the Castle Mountain or Mount Stephen section.

[1] Notes on the geology of Mount Stephen, British Columbia. American Geologist, vol. 3, 1889, pp. 22-25.

[2] Report on the Geological Structure of a portion of the Rocky Mountains, with a section. Geol. Surv. Canada, new ser. 1886-87, 1887, pp. 24-29D.

RÉSUMÉ.

The sedimentation of the western area is much more varied and larger than that of the eastern side of the Rocky Mountains. The southern portion, represented by the Eureka District section, extending from the basal quartzite to the base of the Lower Silurian (Ordovician), is a continuous conformable succession of limestones and calcareous shales, with the exception of a narrow belt of arenaceous shales resting directly upon the lower quartzite. The calcareous sediments are 6,200 feet in thickness and include the faunas of the Middle and Upper Cambrian. The Lower Cambrian fauna is well developed in the shales between the limestone and the quartzite. The Highland Range section, 125 miles to the south, has a thickness of 4,800 feet of limestone, between the quartzite and the Lower Silurian (Ordovician). Proceeding eastward from central Nevada to northern central Utah, the Cambrian formations thin out, and on the flanks of the Wasatch Mountains are represented by 250 feet of argillaceous and siliceous shales above the basal quartzite. In this section only the Lower and Middle Cambrian faunas are found. The three thousand or more feet of limestone, with an abundant Upper Cambrian fauna, found in central Nevada, is unrepresented.

A comparison of the section in the Wasatch Mountains with that of Nevada shows that in both the earlier conditions of sedimentation were apparently the same. But during the deposition of the Upper and Middle Cambrian rocks, in the immediate vicinity of the Wasatch Range, it was an area of minimum deposition of argillaceous sediment, while that of Central Nevada was one of a great accumulation of calcareous sediment.

What the conditions were in the vicinity of the Wasatch Range during the deposition of the great calcareous deposits of central Nevada of Upper and Middle Cambrian times is largely conjectural. The physical appearance of the rocks indicates a shallow sea with very little deposition of sediment during the earlier portion of Cambrian time, and either a very shallow sea without deposition of sediment or a very deep sea without deposition of sediment, during the latter part of Cambrian time. It may be that some sediment was deposited and subsequently was removed by erosion, but this is exceedingly doubtful. The pure limestones of the Lower Silurian (Ordovician) rest directly upon the shales of the Cambrian, without any apparent unconformity.

To the north, near Malade City, Idaho, there are 1,200 to 1,400 feet of limestones that occur above the series of quartzites and slates. The sedimentation is essentially the same as that of central Nevada with the exception of a less amount of calcareous sediment above the basal quartzite. The Upper Cambrian fauna has been found, but not the Middle or Lower fauna. Still farther to the north, in western Alberta, and eastern British Columbia, the same series is represented in the Bow

River quartzites and slates. The Cambrian section at this point also agrees closely with that of Nevada. The Olenellus fauna occurs at the base of a thick series of limestone, and in calcareous shales, 2,000 feet higher up, the Middle Cambrian fauna is well developed. Where the line between the Cambrian and Lower Silurian (Ordovician) is to be drawn in this great series of limestone and calcareous shales is still undetermined.

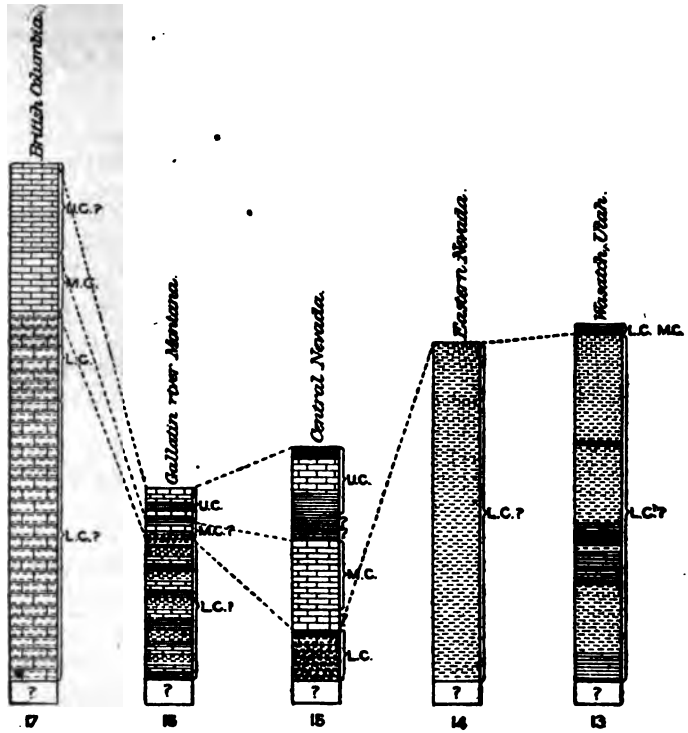


FIG. 3.—Sections of the Rocky Mountain province, vertical scale 6,400 feet to the inch. The number beneath each section corresponds to the locality number on Pls. I and II.

The presence of *Olenellus gilberti* 3,000 feet down in the Bow River quartzite and shales gives strong reason for referring the entire Bow River, Idaho, Wasatch, and Nevada quartzite and shales series to the Lower Cambrian. We know that the vertical range of the fauna is great in the Appalachian sections and also in British Columbia.

As a whole the sedimentation in the vicinity of the shore line of Utah was limited in amount in later Cambrian time, and consisted mainly of siliceous and argillaceous muds. In the deeper sea to the westward a great accumulation of calcareous sediment rests upon the basal quartzite, and this continues to southern central Nevada. To the northward there is a decrease in thickness of the limestones across Idaho. In British Columbia the section is more like that of central Nevada.

A comparison of the sections of the area on the eastern side of the Rocky Mountains with that of the western sustains the view that during late Algonkian?, Lower Cambrian, and Middle Cambrian time the eastern Rocky Mountains and the plains to the eastward were above the sea level, whilst to the west the sediments of the later Algonkian?, Lower Cambrian, and Middle Cambrian were accumulating west of the line of the Wasatch Mountains and the extension of this line nearly due north into British Columbia. Over all this region the coast line and sea bed appear to have undergone a gradual depression during early Cambrian time, and a relatively rapid depression at the beginning of Middle Cambrian time. (Fig. 3.)

THE INTERIOR CONTINENTAL PROVINCE.

This province includes the Upper Mississippi area; the eastern border or Adirondack sub-Province, the western border or Rocky Mountain sub-Province, and the Llano County area of central Texas and the Grand Cañon of Arizona as a minor southwestern sub-Province.

The Lake Superior sandstones and the controversy in relation to them will be noticed under a separate heading, after the description of the recognized Upper Cambrian rocks of Wisconsin, Iowa, and Minnesota and their Canadian extension.

UPPER MISSISSIPPI VALLEY.

In the historical review the literature pertaining to these rocks has been considered under the headings of "Wisconsin," "Minnesota," and "Iowa," but as the strata all belong to one geologic basin it is considered best to speak of them collectively.

The formations that have been correlated with the Potsdam sandstone of New York will be treated of under two headings: (1) The St. Croix or "Potsdam" sandstone proper, and (2) the sandstone of the south shore of Lake Superior.

The St. Croix ("Potsdam") sandstone.—The greater portion of the exposures of the St. Croix or Lower sandstone occurs in Wisconsin, and it here also presents many variations in sedimentation and fauna. Its lower beds rest on the great pre-Cambrian nucleus of the center of the State, extending about it from the Michigan line on the northeast to where it passes into Minnesota on the northwest. Its line of contact with the superjacent Magnesian limestone is also very extended owing to the numerous streams that have cut through the limestone down into the sandstone throughout its line of outcrop. The epoch was one of accumulation of sand. The rocks are mainly light-colored sandstones in central and southern Wisconsin, but embrace some beds of limestone and shale. The maximum known thickness is about 1,000 feet. The fauna is large and varied, and contains trilobites, gasteropods, ptero-

pods, and brachiopods. The succession of beds is, according to Prof. T. C. Chamberlin, as follows:[1]

On the southern side of the Archean Island the lower part of the formation usually consists of coarse quartzose sand, of an exceedingly open, porous nature, with but little aluminous or ferruginous and almost no calcareous matter. Higher in the series the sandstone becomes finer grained and the accessory substances named more abundant. Somewhat above the middle of the series a stratum of shale occurs, attaining a known thickness of 80 feet. This is not everywhere present and seems to be mainly developed at some distance from the ancient shore line. It appears to indicate that for a time there was a deepening of the waters, admitting of the accumulation of fine sediment, except near the shore, where the deposit of sand continued. Above the shale the sandstone, reaching a thickness of 150 feet, is again found. This is medium or coarse-grained and slightly calcareous. It, in turn, is overlain by a deposit of associated shale and limestone (the *Mendota limestone*), which attains a thickness of 35 feet in the vicinity of the lake from which it derives its name. These beds indicate a modification of the conditions of deposition, such as to permit not only the settling of fine sediment, but the accumulation of calcareous mud as well. The latter was doubtless derived from the calcareous remains of life, since the sea then swarmed with living organisms whose shells and skeletons are found entombed in the strata. The frequency of broken and worn fragments implies that the greater portion were ground to powder, forming the calcareous flour that subsequently hardened into limestone. These beds appear to point quite surely to a moderate deepening of the waters.

Overlying this impure limestone is a third and thinner bed of sandstone (the *Madison*) with which the Potsdam series closes. This, on the whole, is finer grained than that below, and is bound more firmly together by cementing material, which is mainly a calcareous and ferruginous infiltration. The thickness of this bed is about 30 feet.

In eastern Wisconsin the formation is divided by Prof. Chamberlain into six parts, as follows, beginning at the top:

	Feet.
Sandstone (Madison)	35
Limestone, shale, and sandstone (Mendota)	60
Sandstone, calcareous	155
Bluish shale, calcareous	80
Sandstone, slightly calcareous	160
Very coarse sandstone, noncalcareous	280

The thicknesses given are subject to considerable variation. As a general rule they grow less toward the northeast. Where the total thickness of the formation is reduced by the inequalities of its Archean bottom it is by the loss of the lower members of the group and not by the thinning of all.[2]

The Upper or Madison sandstone is described as a rather coarse-grained, thick-bedded, compact, but soft, slightly calcareous, light-colored sandstone. In its upper portion, immediately beneath the lower Magnesian limestone, it is at most localities coarse, and the topmost layer is often broken up and mixed with calcareous material, giving it a coarsely brecciated structure. The subjacent limestone (Mendota) consists of a group of alternating strata of arenaceous magnesian limestone, sandy calcareous shales, and shaly and calcareous sandstones.[1]

[1] General Geology. Historical Geology. Paleozoic Era. Geology of Wisconsin. Survey of 1873–'79, vol. 1, 1883, pp. 121, 122.

[Geology of eastern Wisconsin.] Chapters 7 and 8. Lower and Upper Silurian. Geology of Wisconsin, Survey of 1873–'79, vol. 2, 1877, pp. 259, 260.

[2] Op. cit., p. 260.

The upper and lower limits of the Mendota group are scarcely definable. It graduates above into Madison sandstone, so as to make it difficult to draw a line between the two, and below the alteration of calcareous and arenaceous rock make it equally difficult to say where the series ends. The Mendota beds are regarded as the eastern equivalents of Dr. Owen's Fifth Trilobite bed, the common horizon being characterized by the presence of *Dikelocephalus minnesotensis*, *D. pepinensis*, *Lingula aurora*, *L. mosia*, and a few other species of limited horizontal distribution. The lower divisions constitute the main body of the Potsdam sandstone and present but very few exposures in this region. They are divided into four parts.[1]

The strata referred to the Potsdam sandstone by Prof. R. D. Irving in central Wisconsin have a surface distribution of over 6,000 square miles.[2] In the vicinity of Madison the following succession of layers between the Mendota base and the Archean occurs:[3]

	Feet.
1. Greensand layer	1
2. Calcareous and dolomitic, friable, fine-grained, greenish sandstone	31
3. Not known	31
4. Light colored sandstone, for the most part purely siliceous, being made of rolled quartz grains; but no specimens obtained from the uppermost layers	704
5. Red shale	10
Total	777

The generalized section given above for the Potsdam series, below the Mendota base, holds true for a large part of the central Wisconsin district, and would be satisfactory for all of it but for the facts next to be stated.[4]

Prof. Irving then proceeds to describe layers of sandstone and bowlder-conglomerate occurring near the pre-Cambrian quartzite, which apparently occupy a higher position and extend downward across the upper portion of the eastern Madison section. He explains this occurrence on the theory of the accumulation of these conglomerates and sandstones near the shore line at a higher level than the sandstones that accumulated offshore.

The beds of passage between the Potsdam and Lower Magnesian series include, as already said, two well marked beds, 60 to 90 feet in combined thickness—the Mendota limestone and the Madison sandstone.[5]

Of the fauna in the rocks he says:

To the list of fossils of the lower sandstone series given by Prof. Hall but little has been added by the present survey, as far as central Wisconsin is concerned. * * * The general grouping of upper, middle, and lower species appears to hold true as regards the order, but his lower species must really be assigned to the middle of the series, since its thickness is about twice as great as Mr. Hall supposed.[6]

[1] Op. cit., pp. 261, 262.

[2] The Lower Silurian rocks. (Geology of central Wisconsin.) Geology of Wisconsin, survey of 1873–1879, vol. 2, 1877, p. 529.

[3] Op. cit., p. 534. [4] Op. cit., p. 536. [5] Op. cit., p. 542. [6] Op. cit., p. 545.

In the Mississippi Valley, in southwestern Wisconsin, Mr. Moses Strong estimated the total thickness of the Potsdam at 800 to 1,000 feet, the inequalities in the surface of the underlying Archean rocks being the principal source of its variation.[1] The formation is composed almost entirely of sandstone. The only exception to this is the stratum of magnesian limestone and shale found in the upper part of the formation.

The strata of the formation are usually composed of fine siliceous sand, generally in small, rounded, water-worn grains of almost every color, the most frequent being the various shades of yellow and red, sometimes green, and often snow white. The strata vary greatly in consistency, and in different localities the same stratum may present different degrees of hardness. Some of the layers, and especially the white ones, are frequently almost as compact as quartzite, and from this all degrees are found, to a loose, friable sand that crumbles in the hand. * * * The stratification of the Potsdam is very regular and even, and the beds usually lie in a nearly horizontal position over large tracts of country. Indeed, so little do they deviate from an apparent level that the dip can not be distinguished by the eye, but only by a careful measurement. The dip is usually to the northwest, and seldom exceeds 8 or 10 feet to the mile, but more frequently it is less.[2]

The most highly fossiliferous portion of the formation occurs in western Wisconsin. The formation is divided in the lower St. Croix district, by Mr. L. C. Wooster, into four horizons, as follows:[3] (1) "Eau Claire grit; (2) Eau Claire trilobite beds; (3) Hudson trilobite beds, and (4) line of junction with the Lower Magnesian limestone." In this region it borders upon the metamorphic and igneous rocks to the north and east, and touches the Lower Magnesian limestone on the south and west.

The four horizons mentioned are described as follows:

The Eau Claire grit, exposed at the mouth of Eau Claire River, is a very coarse sandstone, with Scolithus tubes in one or two of the layers. The rock is so coarse that it has been termed a conglomerate, not without reason.

The Eau Claire trilobite beds are characterized by several species of trilobites not found at any other horizon, and also by being the lower limit at which brachiopods were found in the sandstone. These beds likewise mark the lower limit of calcareous matter in the formation.

The Hudson trilobite beds lie at the best defined horizon in the sandstone. These beds lie in close relationship to and between the *Lower Calcareous band* and the layers which are richest in green sand, and thus can not well be mistaken. * * * The shaly layers below the trilobite beds are intensely green from the presence of green sand (a variety of glauconite), which, so far as known, is true of no other horizon.

The line of junction with the Lower Magnesian limestone may, in nearly every instance, be recognized by the heavy brecciated beds of limestone just above. But this character may fail in the extreme southeastern border of the district, where it is possible that beds of sandstone are interstratified with the lower layers of the Lower Magnesian limestone, as in eastern Wisconsin.[4]

[1] Geological formations. (Geology of the Mississippi regions north of the Wisconsin River.) Geology of Wisconsin, survey of 1873-1879, vol. 4, 1882, p. 45.

[2] Op. cit., pp. 39, 40.

[3] Detailed geology: [Geology of the lower St. Croix district.] Geology of Wisconsin, survey of 1873-1879, vol. 4, 1882, p. 109.

[4] Op. cit., p. 110.

Another horizon is mentioned in which lies the Upper Calcareous band, possibly marking the horizon of the Mendota limestone of central Wisconsin.

At no one point in the district is the entire formation exposed, and so, to obtain the entire thickness from the Lower Magnesian limestone to the granite below, the sum of the thicknesses of the subdivisions is taken:

	Feet.
From the Lower Magnesian to the Hudson trilobite bed	200
From the Hudson trilobite bed to the Eau Claire Trilobite bed	200
From the Eau Claire Trilobite bed to the Eau Claire grit	240
From the Eau Claire grit to the granite (at Eau Claire), estimated	100
Total	740

The last division is probably much thicker to the south and west, making the thickness of the formation range to 800 and 1,000 feet.[1]

The report of Prof. Wooster contains details of numerous local sections that show the lithologic and paleontologic characters of the formation.

The outcrops in Iowa are the continuation of those of southwestern Wisconsin; and very little is added to the knowledge of the formation in Minnesota, where it is called the St. Croix sandstone by Prof. N. H. Winchell. At Winona and Stockton there are about 303 feet of the formation exposed.[2]

A generalized section in Minnesota, as given by Prof. Winchell,[3] is as follows:

		Feet.	
St. Croix	Jordan sandstone	75–100	= Madison of Wisconsin.
	St. Lawrence limestone	0– 30	= Mendota of Wisconsin.
	Dresbach sandstone and shales	200.	
Shales		(?)	

CANADIAN EXTENSION.

In the account of a deep boring at Rosenfeld Station, on the Canadian Pacific Railway, Dr. G. M. Dawson correlates the upper portion of the section with the Maquoketa shales, beneath which occurs the Galena limestone, passing below into Trenton and then to the St. Peters sandstone. Below this, before reaching the granite, there are 110 feet of dark red, reddish and greenish, bluish and grayish shales, passing below into red shales, which are referred with doubt to the Lower Magnesian limestone.[4] Whether the St. Croix sandstone is represented in this section can not be determined in the absence of paleontologic evidence, but it is not improbable that the horizon of the St. Croix and the Lower Magnesian limestone of the Minnesota section may both be included between the limestone and the granite at the bottom of the well.

[1] Op. cit., p. 112.

[2] The Geology of Minnesota, vol. 1 of the final report. 1884, p. 258.

[3] Winchell, N. H.: 14th Ann. Rep. Minn. Geol. and Nat. Hist. Survey, 1886, pp. 325–337.

[4] On certain borings in Manitoba and the Northwest Territory. Royal Soc. Canada, Proc. and Trans., vol. 4, section 4, 1887, p. 86.

LAKE SUPERIOR SANDSTONE.

The earlier geologists speak of the Keweenawan series and the horizontal Lake Superior sandstones as forming part of the same terrane, and this view has been sustained by some more recent writers. Many others, however, have held the view that the horizontal sandstones were the equivalents of the fossiliferous sandstones beneath the Magnesian limestone of central Wisconsin, and that the sandstones of the Keweenawan series were unconformably subjacent to the horizontal sandstones. Prof. R. D. Irving, taking the latter view, says:

The constant horizontality of the sandstone series, its restriction to low levels, the actual unconformity visible in Douglas County, the proximity of the horizontal sandstones to the enormously thick perpendicular fragmental beds of the Montreal River, and the relations of the two series on the St. Louis appear to amount to demonstration. In the Thunder Bay region the Canada geologists have proved a similar nonconformity, and Sir William Logan's arguments would seem to show that the same is true for the southeastern shore of the lake. That it may at times be difficult to tell whether we have to do with the Keweenawan or the newer sandstones is undoubtedly true in some of those cases where the Keweenawan beds have a low inclination, but such cases of difficulty are rare.[1]

Of the relation of the horizontal sandstones on the north side of the Wisconsin pre-Cambrian area and the fossiliferous sandstone on the southern side he says:[2]

An absolute proof of their exact relations is wanting, because nowhere as yet have the two been traced into each other. Judging from the low altitude above the lake to which the Lake Superior sandstone has been seen reaching, it appears improbable that any connection ever existed between the two formations in the Wisconsin-Minnesota region. * * * It appears, on the whole, that the evidence is all in favor of an approximate equivalency of the Lake Superior and Mississippi Valley Potsdam sandstones. It seems probable to me, with my present knowledge of the facts, that they were deposited in always disconnected basins, and that their sharply contrasted lithological peculiarities are to be explained by corresponding differences in the ancient rocks from whose ruins they are built.

Under the designations of the "Eastern sandstone" and "Western sandstone" Prof. Irving describes the horizontal sandstones of the south shore of Lake Superior. By the "Eastern sandstone" he means sandstone that fills the valley between the Keweenaw or main trap range of Michigan and the so-called south range. The eastern end of this depression is occupied by the waters of Keweenaw Bay. The sandstones skirt the shores in a band varying in breadth from a few rods to 1 or 2 miles, the older crystalline rocks occasionally reaching down to the lake. These conditions prevail as far eastward as Marquette, beyond which point to the eastward sandstone forms all of the shore cliffs as far as the Sault.[3]

[1] Geological Structure of Northern Wisconsin. [General geology of the Lake Superior Region. Geology of Wis., Survey of 1873–'79, vol. 3, 1880, p. 23.

[2] Op. cit., pp. 24, 25.

[3] The Copper-bearing Rocks of Lake Superior, U. S. Geol. Surv., Monograph, vol. 5, 1883, p. 351.

The characters of the sandstone and its relation to the superjacent rock are stated as follows:

The sandstones of the Keweenaw Bay and its vicinity, and eastward thence to White Fish River, are reddish and often highly argillaceous. At White Fish River the red sandstone is overlain by a light-colored sandstone, which is in turn succeeded by a magnesian limestone, in which are casts of Pleurotomaria. This limestone is the Lower Magnesian of the Wisconsin reports and the Calciferous sandrock of the Eastern States. That it is succeeded in regular order by the fossiliferous limestones of the Trenton, Cincinnati, and Niagara groups was long since shown, and has been demonstrated anew of late years by the labors of the geological surveyors of Wisconsin and Michigan. There thus seems little room for doubt as to the correctness of the view held for years by a succession of geological workers in the Lake Superior region from Owen to Rominger, viz, that in the Eastern sandstone we have to do with the same formation, or with its downward continuation, as the fossiliferous Cambrian sandstone which, in the Mississippi Valley, forms the base of the Paleozoic column.[1]

The Western sandstones, or those of the Apostle Islands and the adjoining coast of Bayfield, Douglas, and Pine Counties, are composed of a horizontally placed sandstone, closely resembling in character the Eastern sandstone of Keweenaw Point. The exposures of the sandstone are almost entirely restricted to the vicinity of the shores of the lake, on the mainland, and the Apostle Islands, and have never been seen reaching more than 50 feet above the lake level. Farther west, however, in Douglas County, the horizontal sandstone reaches to 360 feet above the lake.[2] Prof. Irving states that the prevailing color of this rock is some shade of red, from bright brick red to a brownish red or purplish red. Pinkish, straw-colored, and even nearly pure white varieties occur, either blotching the ordinary red rock in small patches, or occurring in layers from an inch to 2 or 3 feet in thickness. A section typical of many of the cliff exposures of the lake shore is as follows:

	Ft.	In.
Red marly clay (Quaternary)	5	0
Shaly sandstone, in layers from one-fourth to one-half inch thick; light reddish to brown, medium-grained, chiefly made up of subangular quartz grains	4	9
Compact sandstone	2	0
Shaly sandstone	0	3
Compact sandstone; pinkish and moderately coarse-grained, chiefly made up of quartz grains, but many white clay spots, indicating the decomposed feldspar	2	0
	14	0

The shaly and massive layers are, however, not constant, and either will grade into the other in a short distance, the shaly kinds being often merely a result of weathering. Often the massive layers have a thickness of 5 feet and upwards, and lie together in considerable thicknesses without intervening thin-laminated seams. In many places round bunches of red clay, from an inch to several feet in diameter, are seen imbedded in the massive sandstone. In other cases the clay lies in limited and

[1] Op. cit., pp. 351, 352.

[2] The Lake Superior Sandstone. [Geology of the Eastern Lake Superior District.] Geol. Wisconsin, vol. 3, 1880, p. 207.

very irregular seams, from a fraction of an inch to several inches thick. Some of the round clay patches appear as if formed by the decomposition of granite or gneiss bowlders imbedded in the sandstone at the time of its formation.[1]

In speaking of these same sandstones Mr. E. T. Sweet says:

In regard to the *age of the Lake Superior sandstones*, but very little in deed can be learned in the western Lake Superior district. So far as my observations have extended, the sandstones are absolutely devoid of organic remains. They are removed many miles and are separated by intervening older formations from the unmistakable Lower Silurian strata.

He considers it has been conclusively shown that the sandstones are of more recent age than the Keweenawan strata.[2]

Dr. C. Rominger concluded from his studies of the Lake Superior sandstone that its Lower Silurian age was unequivocally proved by its stratigraphic position. In its whole extent it is visibly overlaid by calcareous ledges containing fossils peculiar to the Calciferous formation, or, in other cases, by the Trenton limestone. He describes the sandstone east of the Copper Range of the Keweenaw Point and divides it into two sections, an upper and a lower one. He says:

The upper section is composed of light-colored, almost white, sandstones of generally soft, friable nature. The lower section is intensely red colored by iron pigment, and contains various hard, compact ledges, which are valuable building stones. West of Marquette only the lower section of the group is developed; east of it the heights are formed by the upper division; the lower has exclusive possession of the shore as far as Grand Island Bay. East of Grand Island Bay the upper division sinks down to the level of the water, and only in limited spots the lower red-colored strata come to the surface.[3]

On Laughing Whitefish River a section as determined by Dr. Rominger is as follows in ascending order:

	Feet.
No. 1.—Alternations of thin-bedded, hard, often micaceous sandstone slabs, with arenaceous shales (as exposed)	25
No. 2.—A fine-grained, more or less argillaceous red sandstone in layers of 1 to 3 feet in thickness with seams of red shales	12
No. 3.—A hard, coarser-grained, red, or speckled sandstone in heavy ledges up to 4 and 5 feet in thickness, amounting in the aggregate to 15 or 20 feet	15–20
No. 4.—Light-colored, middling soft sandstone in thick layers with seams of quartz pebbles, followed by a few feet of a dark and coarse conglomerate; thickness not accurately ascertained	00
No. 5.—A series of thin-bedded, soft, whitish sandstones, each layer separated from the other by a narrow seam of bluish shale	75–100
No. 6.—Massive soft white sandrock, projecting in vertical walls	50

Directly above this, strata of the Calciferous sandrock occur with casts of Pleurotomaria.[4]

This section of Dr. Rominger's is not altogether complete, but it shows conclusively that the Lake Superior sandstone in the vicinity of Mar-

[1] Lake Superior sandstone [Geology of the Western Lake Superior district]. Geology of Wisconsin, Survey of 1873–'79, vol. 3, 1880, pp. 208, 209.

[2] Op. cit., pp. 351, 352.

[3] Paleozoic Rocks. Geol. Survey Michigan, Upper Peninsula, 1869–1873, vol. 1, pt. 3, 1873, pp. 80–82.

[4] Op. cit., pp. 88–90.

quette, or east of Marquette, occupies the exact stratigraphic position o the fossiliferous St. Croix or "Potsdam" sandstone of Wisconsin. Th description of the character and geologic equivalency of the sandstone of the south shore of Lake Superior as given by Prof. Chamberlin a cords with the view I had formed from the study of the literature pe taining to the subject. Although not considering it proved that the tw sandstones are exactly contemporaneous, I think that for all practic geological classification they may be considered equivalent deposit This view is so well expressed by Prof. Chamberlin that it is he quoted:

Lake Superior sandstone.—The sandstones on the southern side of the Archean L and are light-colored, being mainly yellow or white, varying locally to pink, brow and green. They are nowhere bodily dark. An easy explanation of this is found the fact that they were derived from the light-colored quartzose and granitic roc of the southern face of the land. But passing around to the Lake Superior Basin o the northern side of the island, where erosion preyed upon the iron-bearing membe of the Huronian series, and more especially upon the traps, sandstones, and shales the copper-bearing series, the resulting beds are not only reddish brown in color, b contain a notable ingredient of iron and of shaly material derived from those form tions. Indeed the deposit bears a very close external resemblance to the sandston of the Keweenawan series, and the two have been considered as identical by ab geologists.

Concerning the distinctness of the two formations we entertain no doubtful opi jon. The Potsdam sandstone is habitually horizontal, while the Keweenawan tilted, indicating that the latter partook of a general stratigrapical movement whic did not affect the former, which, considering the attendant circumstances, is equiv lent to saying that the horizontal sandstones were not then in existence. The obse vations of Mr. Sweet in Douglas County are further proof of this.[1] The Potsda sandstone there abuts unconformably against the Keweenawan traps and contai pebbles derived from them, showing not only that they were earlier formed but th they were tilted and extensively eroded at the time the horizontal sandstones we formed. The local disturbance of the latter does not vitiate the force of the eviden when critically considered. Similar phenomena are presented along the southeaste face of the promontory of Keweenaw Point.[2]

Besides these stratigraphical evidences of distinctness, the microscopical observ tions of Prof. Irving and the chemical analyses of Mr. Sweet show an important co stitutional distinction between them.[3] Whereas the Keweenawan sandstones a largely nonquartzose, the horizontal beds are highly quartziferous.

As the latter are traced eastward along the south shore of Lake Superior they a found, according to Dr. Rominger, to be interstratified with and graduated into t light colored sandstones which prevail in the eastern portion of the upper peninsu of Michigan, and which are traceable into direct continuity with the light-color sandstones of Wisconsin. The same geologist (as also Foster and Whitney) is auth ity for the statement that in the Keweenaw Valley Silurian limestone overlies t sandstone.

The southern light-colored sandstones, like their northern equivalents, abut n

[1] Geol. Surv. Wis., vol. 3, pp. 340-347; also 350 352.

[2] This has recently been denied by Dr. M. E. Wadsworth, but more recent examination by expe enced observers shows his discussion of the subject to be more pronunciative than trustworthy. B letin of the Museum of Comparative Zoology, at Harvard College, Geol. Series, vol. 1. The facts detail as determined by the later observations will be found in Prof. Irving's forthcoming report the copper-bearing series.

[3] Geol. Wis., vol. 3, pp. 15 and 350, and microscopical Pl. XIX A.

conformably against eroded cliffs of Keweenawan rock. At St. Croix Falls light-colored Potsdam sandstone containing characteristic fossils reposes unconformably upon and against Keweenawan cliffs and occupies depressions and valleys formed through its erosion. Conglomerates derived from it mark the junction of the two formations and contain Potsdam fossils. Hand specimens may be obtained, having Keweenawan rock for one side and Potsdam sandstone containing shells of *Lingulepis pinnaformis* for the other. The phenomena absolutely forbid any explanation based on faulting or intrusion

North of St. Croix Falls the same strata, sustaining a like stratigraphical relationship (though not seen in actual unconformable contact) may be traced more than half way across the Keweenawan series. Passing the remainder of the interval to Lake Superior the horizontal red sandstones are found abutting, in similar unconformable contact, against the eroded Keweenawan series as above stated. The accompanying section illustrates the general relationship, but only a careful study of the details can make clear the full force of the evidence.

When to these considerations there are added others less susceptible of brief statement, to which we are here confined, it appears that the distinctness of the horizontal Lake Superior sandstone from that of the Keweenawan system and the correctness of its reference to the Potsdam series is sustained by a weight of evidence that would not be seriously questioned but for complications with what we deem the misinterpretations of other geological features of the Lake Superior region. The modifications which the formation assumes in that region are precisely those which its method of derivation demands.[1]

CANADIAN EXTENSION.

On the geological map of the Dominion of Canada, published in 1882, the Nepigon series of rocks is colored Cambrian, both on the shores of Lake Superior and about Lake Nepigon. This is in accordance with the views of Dr. A. R. C. Selwyn.

MISSOURI.

The Cambrian rocks in Missouri occur in the southwestern portion of the State, about the Ozark Uplift. As far as known they are of Upper Cambrian age and consist of a sandstone that occurs beneath the third magnesian limestone, or Calciferous, and the fourth magnesian limestone of the Missouri survey, beneath which, according to Prof. G. C. Broadhead, there are other arenaceous and calcareous beds.

The third sandstone is doubtfully identified by Mr. F. B. Meek, in Miller County, as 6 feet of white sandstone, composed of rounded grains of quartz cemented in part by calcareous matter. Subjacent to this there are 27 feet of hard gray and light flesh-colored magnesian limestones in rugged, irregular beds from 5 to 8 feet in thickness.[2] In Morgan County the third sandstone is known to occur at a few localities, where it varies from 25 to 30 feet in thickness. The subjacent fourth magnesian limestone forms a bluff 150 feet high above the Osage River in the southwestern part of the county.[3]

[1] General geology. Historical geology. Paleozoic era. Geology of Wisconsin, survey of 1873–1879, vol. 1, 1883, pp. 122–124.

[2] Reports on the Geological Survey of the State of Missouri, 1855–1871, 1873, p. 127.

[3] Op. cit., p. 148.

In Madison, St. Francois, and Iron Counties, Prof. G. C. Broadhead found beneath the third magnesian limestone the following downward succession:

(3) Siliceous or grit-stone bed, with intercalated magnesian limestone.
(2) Marble beds.
(1) Sandstones, conglomerates, and shales.

In No. 3 *Lingulella lamborni* Meek has been found. The marble beds or No. 2 appear to be confined to the southwest quarter of Madison and the central and northern parts of Iron and extend into Reynolds County. The greatest thickness is not over 30 feet, and they are not always present.

No. 1 is confined chiefly to the northern part of Iron and Madison, extending to St. Francois. The entire thickness of this as well as the regular order of its various beds is rather difficult to arrive at. But we find both in Iron and Madison Counties coarse conglomerates resting on granite and porphyry. We also find sandstones which are sometimes very coarse, and at other times fine grained, resting on conglomerates. We also find shale or slate beds reposing on granite and underlying sandstone. Similar shale beds are also intercalated with the sandstone. In the neighborhood of Mine La Motte this sandstone reaches to over 100 feet in thickness, and is also found to be the lowest rock directly resting on the granite. Borings with diamond drill on the Mine La Motte property indicate magnesian limestone, with some siliceous beds, 80 feet; sandstone, 63 feet; granite.

On St. Francois River, in Madison County, these lower sandstones rest directly on the granite and are unaltered; on Twelve-Mile Creek, Madison County, the marble beds and sandstones rest unaltered on the porphyry, and on Big Creek, Iron County, heavy beds of unaltered magnesian limestone rest directly on the porphyry.[1]

At the deep well of the St. Louis County insane asylum, beneath the third magnesian limestone, the drill passed through, going down—

98 feet of third sandstone.
384 feet of fourth magnesian limestone.
54 feet of Potsdam sandstone.

At the base of the sandstone it entered what was supposed to be granite, although the line of demarkation between the sandstone and the granite was not well defined.[2]

In the descriptive geology of Madison County Prof. Broadhead states that the sedimentary rocks were deposited across the valleys between the mountains and the hills (that is, of the old pre-Cambrian land surface). The order of deposition, commencing at the oldest, is—

(1) Sandstones, conglomerates, and shales.
(2) Marble beds.
(3) Grit-stone beds and rough beds of magnesian limestone.

Above this comes the magnesian limestone referred to the Calciferous.

In the vicinity of Fredericktown there is a series of grits between the grit-stone beds and the superjacent magnesian limestone in which *Lingulella lamborni* has been found. It is stated that in the lower portion

[1] Geological Survey Missouri, including field work of 1873–1874, vol. 1, 1874, pp. 31, 32.
[2] Op. cit., p. 32.

of the magnesian limestone *Lingula lamborni*, Orthoceras, a turbinated Gasteropod, and a coral, resembling in cross-section a Zaphrentis, were observed. He states that probably this magnesian limestone can also be included in the Potsdam zone.[1] This includes all the limestones up to the base of the recognized third magnesian limestone.

A more detailed account of this lower marble belt is given by the same writer in a description of the marbles of southeastern Missouri. The most typical section is that of the northern part of Madison County, which is summed up as follows:

(1) Magnesian limestone.
(2) Eighteen feet of thick beds of siliceous dolomite and thin shaly limestone, with *Lingula lamborni*.
(3) Twenty-three feet of gritty dolomite.
(4) Five to thirty feet of marble.
(5) Five to forty feet (as much as 90 feet near Mine La Motte) of sandstone.
(6) A few feet of slaty sandstone resting on granite.

The presence of *Lingula lamborni* in beds a little above the marble will certainly assign the marble beds to the Potsdam group.[2]

EASTERN BORDER OR ADIRONDACK SUB-PROVINCE AND ITS CANADIAN EXTENSION.

The geographic distribution of the Potsdam terrane about the Adirondacks is delineated on the geological map of New York accompanying the final report in 1842, and that of the Canadian extension on the small map accompanying the 1863 report of Sir W. E. Logan and the large map of Messrs. Logan and Hall, published in 1866.[3]

On the western side of the Adirondacks the outcropping of the sandstone is first seen in the northern part of Lewis County, where it rests unconformably upon the subjacent Archean rocks and passes above into the calcareous layers of the Calciferous formation. The outcrop broadens to the north in Jefferson and St. Lawrence Counties and extends around the northern side of the Adirondack area through Franklin and Clinton Counties to Lake Champlain. The exposures on the eastern side are more or less interrupted, and rarely occur upon the eastern side of the lake in Vermont, except in Addison and Rutland Counties. On the southwestern side outcrops occur in Washington, Warren, and Saratoga Counties.

The Franklin and Clinton County area extends across the boundary into Canada, forming quite an extended exposure within the triangle formed by the St. Lawrence and the St. John's Rivers and the boundary, and at one point it crosses to the north of the St. Lawrence River. From St. Lawrence County the sandstone crosses the river and extends along the western side of the Ottawa Basin.

[1] Geological Survey Missouri, including field work of 1873-1874, vol. 1, 1874, pp. 357, 358.
[2] Marble of Southeast Missouri. Kansas City Review, vol. 5, 1882, pp. 525, 526.
[3] Geological map of Canada and part of the United States from Hudson's Bay to Virginia and from the Missouri River to Newfoundland. Montreal, 1866.

The typical sections are those of Potsdam, in St. Lawrence County; Chateaugay Chasm, in Franklin County; Au Sable Chasm, in Essex County, and Greenfield, in Saratoga County, in the State of New York, and Hemmingford, in Canada.

Section at Potsdam.—At the type locality of the terrane at Potsdam, in St. Lawrence County, there are but 60 or 70 feet of the rock exposed. It occurs in layers from an inch or two in thickness up to 2 feet, and the general color of the mass is yellowish brown to reddish brown, particularly the latter color in the thicker layers.

Section at Chateaugay Chasm.—At Chateaugay Chasm, Franklin County, one of the best sections of the formation upon the northern slopes of the Adirondacks is exposed. I studied it in 1888 and found that 5 miles south of the Ogdensburg and Lake Champlain Railway the pre-Cambrian rocks are to be seen on the hills west of the river and in a few small outcrops about one-half a mile to the north. It is a bedded, reddish gneissoid and hornblendic rock, probably of Algonkian age. Nearly one mile south of these outcrops the Potsdam sandstone appears in the bed of the river, with a northwest dip of about 3°. The exposures increase rapidly in thickness, and bluffs from 50 to 75 feet in height, formed of evenly-bedded layers, rise above the water. The river has worn a cañon through these beds for three-quarters of a mile down to a mill and pond, where the cliffs break away, and the strata, losing their dip, continue to the south, in nearly horizontal beds, to the crossing of the railroad embankment.

The fall in the river bed is rapid, and at the High Falls of the Chateaugay Chasm a bluff of 125 feet rises from the foot of the fall. The lower 35 feet of the section is formed of coarse reddish and gray sandstone in massive layers. At the Narrows, three-fourths of a mile farther down the stream, the lower beds are 75 feet in thickness and pass into massive bedded grayish and buff-colored sandstones that break up into thinner layers on exposure to the action of the weather. Many of the massive beds are made up of irregular cross-bedded layers; this is best seen about a mile below the falls. The strata below assume a southwesterly dip of 2° to 3°, which carries the entire sandstone formation beneath a hard light gray sandstone a little north of the mouth of the chasm. One hundred and fifty feet of sandstone, not included in the section above the railroad embankment, is exposed in the chasm and 25 feet of the upper beds occur below the mouth of the chasm. This gives a total thickness of 250 feet of sandstone as the known thickness of the Chateaugay section. To this there is to be added an unknown amount at the base and 25 feet of passage beds between the upper sandstone and Calciferous sandrock, to be seen just above the entrance of Marble River into the Chateaugay.

SECTION.

(From the base upward.)

	Feet.
(1) Coarse sandstone with occasional layers of conglomerate near the base..... Color reddish brown near the base, buff, gray, and buff and gray, spotted with grains of reddish brown sand. Texture compact and hard, with bands of a soft friable nature.	75
(2) Massive bedded, grayish and buff, rather coarse sandstone, many of the layers cross-bedded	150
(3) Compact, fine-grained white sandstone, some of the layers of which are discolored and broken by small reddish brown cavities. *Lingulepis acuminata* occurs in the upper portion, and 10 feet higher up *Ophileta compacta*, *Dikelocephalus* sp. ?, *Ptychaspis* sp. ?	25

The stratigraphic exposures are not continuous, the section being broken in places by concealment under the drift. Nos. 1 and 2 are fairly well connected by lithologic features and No. 3 rests on typical strata of No. 2, only a short distance intervening between the outcrops. No. 3 is well shown on Marble River one mile southeast of the Chateaugay Chasm, and the Calciferous sandrock is shown a little farther down the stream. The species found in the upper part of No. 3 are identical with those found in the limestones of the Upper Cambrian in Saratoga County, New York and fully prove that the fauna of the Potsdam sandstone is the same as that of the St. Croix sandstones of Wisconsin.

Section in Hemmingford.—To the northeast of Chateaugay, across the boundary, in Hemmingford, Canada, a section of the sandstone according to Sir W. E. Logan, is 540 feet in thickness. On the south side of Hemmingford Mountain about 180 feet of a coarse gray sandstone are visible, in some parts constituting a conglomerate, with rounded pebbles of white quartz, varying in diameter from an eighth to three-quarters of an inch, while in some parts of the rock there are thinly disseminated flat pieces of black or green shale 1 or 2 inches in diameter by an eighth of an inch thick. The general color of the rock is gray, but greenish and reddish beds occur, and the three colors sometimes follow one another in thin stripes with various alternations. Above the strata of the ravine the hill contains about 120 feet of gray sandstone, the lower half of which is rather coarse grained, and below the same strata 240 feet. Neither the base nor the summit of the sandstone was observed.[1] Farther to the north along the shore of the St. Lawrence occur the celebrated fossil track localities described by Logan.

Section at Keeseville and in Au Sable Chasm.—About one-quarter of a mile above the village of Keeseville, on the Au Sable River, a rounded boss of granite shows on the south bank. Nearly 400 feet lower down the stream, on the opposite side, an evenly bedded and cross-bedded

[1] Geological Survey of Canada: Report of Progress from its commencement to 1863. Montreal, 1863, p. 88.

compact gray sandstone occurs, lying in nearly horizontal beds. Lower down they dip 3° to 5° to the northeast. This dip increases to 7° to 8° at the iron bridge. Following across the strike down the stream to where the beds are horizontal, above the entrance to the Chasm, the measured section shows 333 feet in thickness from near the granite to the highest beds observed.

The section as measured from the mouth of the Au Sable Chasm to the summit beds above the fault is as follows:

SECTION.

	Feet.
(1) Compact, fine-grained, steel-gray, buff, and light gray sandstone, in layers from 6 inches to 5 feet in thickness (20 layers). Strike N. 30° E. Dip. 5° E.	45
(2) Massive layers, light gray, fine-grained sandstone, very hard, breaking up into thin layers, ½ to 3 inches thick	6
(3) Compact, gray sandstone in three layers; 1 foot 5 inches, 1 foot 6 inches, 2 feet 1 inch	5
(4) Light gray and buff sandstone, three layers	4·6
(5) Light gray compact sandstone, with *Lingulepis acuminata*, Conrad. Strike N. 30° E. Dip 5° E., at foot of rapids.	1
(6) Light gray, fine-grained, compact sandstone, in layers varying from 6 inches to 18 inches in thickness	6
(7) Of the same general character as 6, in massive layers, breaking up into thin layers on exposure. Occasional layers contain many small, flat concretions of clay shale and also fragments of Lingulepis. At 34 feet from the base *Hyolithes primordialis?* and *Lingulepis acuminata* occur near the boat-landing in the Chasm. Thirty-five feet higher up in the same light gray compact sandstone *L. antiqua* occurs in association with *Ptychoparia minuta*	117

At this line a fault breaks the section with a down-throw to the northeast. The river and Chasm follow the fault from the Elbow to the Devil's Oven, where the section is taken up again.

(1) Massive layers of light gray, hard, compact sandstone. Prof R. P. Whitfield found at this horizon *Palæacmea typica*, *Ptychoparia minuta*	30
(2) Evenly bedded gray, buff, and yellowish sandstone, hard, compact and in layers 1 to 4 feet in thickness	165
(3) Thinner bedded gray and buff sandstone, with Protichnites tracks above the mill-dam and above the bridge at Birmingham. Strike NE.; dip 5° SE.	45

Ripple marks are very numerous and *Lingulepis acuminata* is abundant 15 feet above the Protichnites bed, and extends about 25 feet to the top of the section. Some of the layers are a little calcareous and full of annelid trails and borings.

Estimating the amount of repetition of strata in the two sections there remains a lower series of 210 feet, and an upper of 140 feet, or a total thickness of 350 feet with the summit and base of the formation unseen.

Section at Whitehall.—There is a fine section exposed at Whitehall, New York, that serves to correlate the sections of Chateaugay and Au Sable Chasm. At the former the upper fauna is present and at Au Sable Chasm the *Ptychoparia minuta* subfauna. At Whitehall the

upper fauna occurs in the upper portion of No. 17 of the following section and the lower in the lower part of No. 15. This is the relative position of the same subfaunas in the Wisconsin section.

Section beginning below lower lock of canal at Whitehall:

	Ft.	In.
(1) Massive bedded, compact, dark steel gray sandstone, almost a quartzite.	25	0
(2) Dark clay shale	0	6
(3) Bluish gray, brecciated limestone	0	6
(4) Fine grained, compact, steel gray limestone	1	0
(5) Compact, arenaceous limestone	3	0
(6) Compact, fine grained, steel gray sandstone in layers of 6 inches to 3 feet. Partings of coarser sandstone and small, flattened clay concretions occur, also streaks of light-colored sandstone in the layers, and cross-bedding is of common occurrence	14	5
Annelid trails on the surface of the layers. Strike N. 20° E.; dip 6° to 8° E.		
(7) Calciferous sandstone in one layer	2	7
(8) Fine grained, compact, steel gray sandstone	20	0
(9) Thin bedded sandstone and clay shale	1	3
(10) Compact, gray and purplish, fine grained sandstone, streaked with dark sandstone and shaly matter; slightly calcareous in places	16	6
(11) Dark gray calciferous layers, weathering to a reddish brown sandstone.. Annelid trails and borings.	2	0
(12) Gray, compact sandstone	1	3
(13) Dark gray, calciferous layers, weathering to a reddish brown sandstone. Annelid trails and borings.	1	4
(14) Hard, compact, gray sandstone, in evenly bedded layers 6 inches to 3 feet in thickness of the division of the typical Potsdam sandstone. Summit near crossing of private roadway	59	8
(15) Sandstones similar to 14, but with few alternating calcareous layers; the calcareous matter decomposing and leaving streaks of reddish and brown rocks in the layers	113	0
Ripple marks occur on the surface of many layers and annelid trails on the calcareous strata, About 30 feet up found *Palæacmæa typica*, H. and W. Strike 25° E.; dip 10° E. The light gray compact limestone, with the little flattened concretions of clay and the cross-bedding, give this portion of the section a striking resemblance to that of the upper 150 feet of the Keeseville section.		
(16) Lead colored calciferous sandstone, weathering rough	0	5
(17) Alternating, gray, compact, fine grained sandstone, reddish coarse sandstone and finer calcareous sandy layers. *Lingulepis acuminata* and *Ptychoparia* sp ? occur in the upper layers, about 40 feet up	70	0
	332	5

Calciferous.

(18) Calciferous sandstone with a massive bedded light gray compact sandstone; at top 10 feet thick	40	
The upper 30 feet of 17 and all of 18 may be considered as the passage beds to the calciferous sandstone above.		
(1) Lead colored, massive bedded, calciferous sandstone	230	
(2) Lead colored, brecciated limestone overlain by a compact light gray limestone	20	

Section at Saratoga.—The section, as determined north and west of Saratoga Springs, and north as far as Corinth, New York, has, at the base, about 200 feet of evenly bedded, compact, grayish to yellowish colored sandstone, that rests unconformably against or upon spurs or ridges of pre-Cambrian gneiss. Including the upper beds of sandstone, the section 3 miles north of Saratoga village gives in ascending order:

	Feet.
(1) Sandstone	40
(2) Oolitic limestone	30
(3) Dark gray, evenly bedded limestone	50
(4) Unfossiliferous, impure, compact, more or less siliceous limestone	95
(5) Massive-bedded, slightly magnesian, gray and dove colored limestones with numerous small, narrow-chambered cephalopods near the summit	35
(6) Massive layers of steel-gray, more or less arenaceous limestone	125
(7) Bird's-eye limestone	6
(8) Black River limestone	4
(9) Trenton limestone	40

The limestone (2, 3) capping the sandstone (1) of the section is also found at Whitehall and at Comstock's Landing, Washington County, New York, where it has been, as was the limestone (2, 3), referred to the Calciferous. The limestone 2 and 3 appears to have been, on the southwestern side of the Adirondack Mountains, the closing deposit of the Cambrian; and there is but little doubt that if we could find a fauna in the limestone (4) of the section it would serve to connect the Cambrian and Lower Silurian (Ordovician) faunas.[1]

The following fauna was found in No. 3 of the section:

Cryptozoa proliferum.
Lingulepis acuminata.
Platyceras minutissimum.
hoyti.
Metoptoma cornutiforme.
simplex.
Billingsia saratogensis.
Matthevia variabilis.
Dikelocephalus hartti.
speciosus.
Ptychoparia calcifera.
(A.) saratogensis.

The comparison of the Chateaugay Chasm section with that of Saratoga County proves very clearly by the included faunas that the Potsdam epoch closed on the south side of the Adirondacks with a deposit of limestone carrying the Dikelocephalus fauna. It is found in the upper beds of the quartzite on Marble River in the township of Chateaugay, and in each section the Calciferous formation is superjacent to the closing epoch of the Potsdam.

The greatest depth reached in the formation is that of the section of Hemmingford Mountain. Unfortunately this section has not been studied so as to determine whether there is any fauna present in the sandstones. The section at Au Sable Chasm, however, shows that a second horizon of the Upper Cambrian fauna occurs about the Adirondacks. This is the zone of *Ptychoparia minuta*, corresponding to the zone of *Ptychoparia minor* of the Wisconsin section.

[1] Second contribution to the studies of the Cambrian faunas of North America. U. S. Geol. Survey Bull. No. 30, 1886, p. 22.

The presence of the Potsdam terrane on the south side of the Adirondacks, along the valley of the Mohawk, has not been positively proved. At Little Falls a thin layer of sandstone, resting unconformably upon the pre-Paleozoic rocks and beneath the Calciferous sandrock, has been referred to the Potsdam. The discovery by Profs. Shaler and Williams of a thin layer of shale, resting upon this layer of sandstone, on the north side of the river at Little Falls, in which specimens of *Lingulepis acuminata* occur, lends more authority for the statement that the Potsdam is present; but as the species *Lingulepis acuminata* ranges up into the Calciferous sandrock, both at Whitehall, New York, and on the north side of the Adirondack Mountains in St. Lawrence County, it is doubtful if we can claim the presence of the Potsdam at any point in the Mohawk Valley. There is not, however, any definite reason why a thin bed of it, with the typical Potsdam fauna, should not be found beneath the Calciferous, if it is not concealed by the overlap of the superjacent Calciferous and Trenton terranes.

The sediments of the Adirondack sub-Province and its Canadian extension, with a single exception, were accumulated in a shallow sea not far removed from the shore-line. Ripple-marked sandstones and trails of marine invertebrates occur. The sandstone is relatively fine-grained with the exception of a small deposit of conglomerate in St. Lawrence County, New York. The formation belongs to the Upper Cambrian, and overlaps upon the sloping shores of the pre-Cambrian land. The one exception to the arenaceous deposit are the limestones in Saratoga County, New York, which were deposited on sandstone and overlap on to the pre-Cambrian rocks. The fauna of the limestone is the same as that of the quartzite at Marble River, near Chateaugay Chasm, on the northern side of the Adirondacks.

WESTERN BORDER OR ROCKY MOUNTAIN SUB-PROVINCE.

This includes the Cambrian rocks of South Dakota, southern central Montana, central and northwestern Wyoming, and Colorado.

SOUTH DAKOTA.

The chief summary of our knowledge of the Cambrian rocks of the Black Hills of Dakota is taken from the reports of Messrs. Newton and Carpenter. The sandstone identified as the "Potsdam" is the lowest member of the fossiliferous series, and in numerous and excellent exposures its character and relations are easily determined and studied. It everywhere rests unconformably upon the upturned edges of the underlying Algonkian slates and schists, filling up irregularities in their surfaces, and its basal member is generally formed of coarse materials derived from the erosion of the subjacent rocks. Consisting mainly of coarse and friable sandstones, with conglomerates easily eroded, it covers superficially very limited areas.

By a reference to the geological map accompanying the report of Mr. Henry Newton the exposures of the "Potsdam" sandstone will be seen

to form a very narrow band surrounding the "Archean" area. Though essentially a sandstone formation it has some variety of composition. Usually it carries a conglomerate at the base, but this is sometimes exchanged for a dense quartzite, and in many places there are interstratified beds of quartzite. In a few localities the formation is quite calcareous and in a great number it contains peculiar greensand deposits. Its thickness is quite uniform, ranging generally from 200 to 250 feet, but attaining to 300 feet on the north branch of Redwater Creek. Complete sections from the "Archean" to the Carboniferous are rarely met with, but one measured in the eastern cañon of Spring Creek by Mr. Jenney is as follows:[1]

Archean.

Feet.

(1) Argillaceous slates, dipping 60° west .....

Potsdam.

(2) Brownish yellow conglomerate, with quartz pebbles, resting unconformably on 1 and dipping 25° northeast 25

(3) Reddish brown sandstone, thinly bedded at base and alternating with soft, shaly sandstones, containing large fucoids, Lingulepis, and fragments of trilobites 200

Carboniferous.

(4) Reddish brown, or pinkish calcareous sandstone, thinly bedded, containing *Spirifera camerata*, cyathophylloid corals, and crinoid columns 20

(5) Limestone: *Spirifera camerata*, Productus, etc 335

Many details are given of the local phenomena presented by the sedimentation and mode of occurrence of this formation; extended comparisons are made between it and the correlated sandstones about the Big Horn and Wind River Mountains of Wyoming, the sandstones of the Mississippi Valley, and the typical Potsdam sandstone about the Adirondacks of New York.

The following is a list of the fossils found in the sandstone and identified or described by Prof. R. P. Whitfield:[2]

Palæochorda prima.
Palæophycus occidentalis.
Palæophycus.
Scolithus.
Lingulepis pinnaformis.
cuneolus.
perattenuatus.
Lingulepis dakotensis.
Obolus? pectenoides.
Obolella polita.
nana.
Crepicephalus centralis.
planus.

Prof. F. R. Carpenter describes the "Potsdam" in the Black Hills as follows:

The present site of the uplift existed as a slowly sinking island in the Potsdam ocean, probably the last surviving land of a vast area eroded and submerged by

[1] Newton, Henry: Geology. Report on the Black Hills of Dakota. U. S. Geog. and Geol. Survey of the Rocky Mountain region, J. W. Powell in charge, 1880, p. 88.
[2] Op. cit., p. 107.

the advancing waters. The base of the Potsdam entirely around its outcrop is a conglomerate. The ocean advanced upon the land with an action that has been aptly termed that of a horizontal saw. The cliffs were undermined by its action, the débris thus formed worn to bowlders, to gravel, and to sand. As the shore-line advanced and a given point became farther from land, it received finer and finer sediments, until sedimentation, in this area at least, entirely ceased.[1]

He calls attention to the fact that the sandstone thins out towards the central portion of the Black Hills uplift. Near Harney Peak the last outliers are about 50 feet thick between the unconformable subjacent "Archean" rocks and the undisturbed conformable superjacent Carboniferous limestone.

WYOMING.

There has been comparatively little detailed information published relating to the Cambrian rocks of the Big Horn Mountains. Dr. F. V. Hayden visited the range in 1861 and found the nucleus composed of red feldspathic granite and a series of stratified Azoic rocks. Resting on these occur the sandstones which are referred to the "Potsdam." He found a few thin layers of fine calcareous sandstone filled with fossils characteristic of the period.[2] These were studied by F. B. Meek, who identified Conocoryphe and perhaps Dikelocephalus.[3]

According to Prof. T. B. Comstock, the sandstone referred to the Potsdam attains a thickness of about 200 feet in the region of the Wind River Mountains, and above the sandstone on the eastern side, along the central portion of the range is a series of limestones resting on the sandstone, having a thickness of about 200 feet. From specimens collected in the limestone he identified a trilobite of the genus Dikelocephalus, several specimens of what was supposed to be *Orthis tritonia*, and a quantity of a species of Theca.[4] As far as Prof. Comstock's observations extended the sandstone rested unconformably upon the subjacent metamorphic rocks.[5] On the map accompanying the report the "Potsdam" formation is represented as occurring all along the eastern side of the Wind River range, and also along the central portion of the western side. The latter occurrence, however, is denied by Dr. A. C. Peale.[6] Dr. Hayden noted in 1862 the presence of a sandstone resting upon the vertical edges of the Azoic clay slate series in the Laramie Mountains, which he referred to the age of the Potsdam sandstone,

[1] Notes on the geology of the Black Hills. Preliminary Rep. Dakota School Mines, on the Black Hills of Dakota, 1888, p. 31.

[2] Hayden, F. V.: Sketch of the geology of the country about the headwaters of the Missouri and Yellowstone Rivers. Am. Jour. Sci., 2d ser., vol. 31, 1861, p. 234.

[3] Meek, F. B.: Preliminary paleontological report with remarks on the ages of the rocks, etc. U. S. Geol. Surv. of the Terr., Sixth Ann. Rep., 1873, p. 465.

[4] Geological Report. Report upon the reconnoissance of northwestern Wyoming, made in the summer of 1873, by William A. Jones. 1874, pp. 108–110.

[5] Op. cit., p. 106.

[6] Report on the geology of the Green River district. U. S. Geol. Surv. of the Terr., 11th Ann. Rep., 1879, p. 524.

although no organic remains were found. In the vicinity of the headwaters of the Niobrara River he measured a section as follows:

	Feet.
(1) Quartzose sandstone, some parts filled with pebbles	22
(2) Red argillaceous slate	5
(3) Sandstone, dull reddish ferruginous, like bed 1, above	37
(4) A series of strata more or less inclined, composed of gneiss with silvery mica in large plates, micaceous and talcose slates, white quartz, etc.	

He states further that he has no doubt the Potsdam sandstone occurs in the form of an outcropping belt all along the Laramie range of mountains, although he was unable to discover any organic remains. He correlated it with the Potsdam on the evidence afforded by the Black Hills section of Dakota. The occurrence of the sandstone at this horizon is noted by him at numerous localities on the flanks of the Laramie Mountains.[1] In opposition to the view of Dr. Hayden may be cited that of Mr. Arnold Hague, who states that all paleontological evidence obtained from the beds associated with the quartzite and above them tend to show that they belong to the Coal-Measure limestone.[2]

In 1871 Dr. Hayden found Obolella and a Lingula in a considerable thickness of Potsdam sandstone on the south side of the Sweetwater River, near the southeastern termination of the Wind River Mountains, thus establishing by paleontologic evidence the Upper Cambrian or Potsdam age of the sandstone referred to that horizon in 1861.[3]

A small area of paleozoic rocks on the northwestern end of the Wind River range has, according to Prof. Orestes St. John, a sandstone at the base that rests on the Archean. It is coarse grained, grayish, buff, reddish stained, thin bedded, with oblique laminated layers and locally quartzitic. The greatest exposed thickness of this bed probably does not exceed 50 feet. Its exact relation to the underlying Archean rocks and to the superjacent strata referred to the Quebec was not determined.[4] On the diagrammatic section accompanying the report formation No. 2, or the Potsdam, is represented as resting unconformably upon the Archean and conformably subjacent to limestones referred to the Quebec.

The Cambrian strata of northwestern Wyoming are contained within the district of the Teton range, Gros Ventre range, and the Buffalo Fork Mountains, all of which are reported upon by Prof. St. John. He quotes Prof. Bradley in relation to the lower quartzite, stating it to be a very compact ferruginous quartzite, with a thickness of from 50 to 75 feet. Above this occurs about 300 feet of sandstone strata on the

[1] Hayden, F. V.: The Primordial Sandstone of the Rocky Mountains in the Northwestern Territories of the United States. Am. Jour. Sci., 2d series, vol. 33, 1862, pp. 70, 71.

[2] Descriptive Geology. U. S. Geol. Expl. of the Fortieth Par.; vol. 2. Washington, 1877, p. 76.

[3] Report of F. V. Hayden (on the geological survey of Wyoming). U. S. Geol. Surv. of the Terr., 4th Ann. Rep., 1871, p. 33.

[4] Report on the geology of the Wind River district. U. S. Geol. Surv. of the Terr., 12th Ann. Rep., 1883, p. 253.

higher slopes of the mountains, according to Prof. Bradley, in the Teton range. The same series of deposits evidently occurs in the Gros Ventre range, and in the Buffalo Fork Peak uplift. In the Gros Ventre range the quartzites were seen in immediate contact with the unconformable Archean schists.[1]

The superjacent limestone, called the "Lower Quebec limestone" by Prof. St. John, occurs in the Teton range and the Gros Ventre. But it is in Buffalo Fork Peak that the best section was obtained. Here there is an exposed thickness of from 50 to 75 feet of bluish and dark drab, brecciated, thin bedded, rough weathering limestone, above which occurs what he calls the passage beds to the "Upper Quebec limestone." These beds are yellowish, arenaceous, micaceous clay, with indurated layers charged with a small orbiculoid shell and thin layers of dirty drab limestone, the weathered surfaces of which are crowded with the fragmentary remains of trilobites and other fossils. Among others there have been identified the genera Conocoryphe and Dikelocephalus. The upper portion of the deposit is here composed of bluish drab shales and brownish gray shaly sandstones. It reaches a probable thickness between 100 and 200 feet.

The superjacent limestone called the "Upper Quebec limestone" shows almost the same development in the Teton and Gros Ventre ranges and the Mount Putnam area of Idaho. The rock consists of generally thin bedded, fragmentary, sometimes brecciated limestones, color gray, grayish buff, and pinkish, carrying small sized trilobites and a gasteropod resembling Raphistoma. In the Teton range the series of rocks has a thickness of 100 feet or more, and forms mural exposures on the cañon walls.

A review of the reports of Messrs. Bradley and St. John shows that the Upper Cambrian horizon is to be recognized in the Teton, Gros Ventre, and Buffalo Peak Mountains, and that it is composed of a basal zone of varying thickness, upon which rests a limestone carrying Upper Cambrian fossils. This limestone is the equivalent of the "Lower Quebec" of Prof. St. John's section. His "Upper Quebec" is to be referred to the base of the Lower Silurian (Ordovician) or corresponding to the Calciferous zone of the New York section.

COLORADO.

The identification of rocks of Cambrian age in Colorado has been made, with one exception, upon stratigraphic and lithologic evidence. The exceptional instance is that mentioned by Mr. S. F. Emmons, who found a distinctly Upper Cambrian genus, Dikelocephalus, in a bed of greenish chloritic shale that he assumed to occur above the main body of the quartzite and near the base of the transition series that passes

[1] Report of the geological field work of the Teton division. U. S. Geol. Sur. of the Terr., 11th Ann. Rep., 1879, p. 481.

into the Silurian limestone.[1] He describes the strata in the Mosquito range referred provisionally to the Cambrian as follows:

The beds assigned provisorily to this horizon * * * are prevailingly of quartzite. To them, therefore, the local name of Lower Quartzite has been given. There average thickness is about 150 feet to 200 feet, of which the lower 100 feet are composed of finely and rather thinly bedded white saccharoidal quartzites, while the upper 50 feet are shaly in character and more or less argillaceous and calcareous, passing by almost imperceptible transition into the siliceous limestone of the Silurian formation above.

At the very base of the series, at the contact with the underlying Archean, wherever this could be observed, is found a persistent bed of fine grained conglomerate, from a few inches to a foot in thickness, made up of rounded and finely polished grains of bluish translucent quartz, generally not larger than a pea in size. Above this is a white quartzite of remarkably uniform and persistent character, always very readily distinguishable as a white band in the numerous sections offered by the cañon walls of the range. Its thickness, when measured on the west side of the range or near the Sawatch Island, is, as mentioned above, 100 feet of purely siliceous beds. On the east side of the range the thickness seems somewhat to diminish, and in places was found to be only 40 feet. * * *

Owing to their similar lithological character and to the general absence of fossil evidence it is difficult to establish a hard and fast line between this and the succeeding formation above. In practice the line has been drawn at the top of the shaly beds, and the commencement of the beds of more massive limestone. The transition beds consist essentially of alternating bands of calcareous quartzite and shales. The name sandy limestones is often applied to them for the reason that on weathered surfaces of the cliff faces they appear like sandstones, the carbonate of lime having been entirely washed out, and only the fine quartz grains left on the thin surface crust.[2]

As already stated, the only fossil remains found in this series occur in a bed of greenish chloritic shales on the east flank of Quandary Peak, about a mile above the Monte Cristo mine. They belong to the genus Dikelocephalus, and closely resemble *Dikelocephalus minnesotensis* of the Potsdam formation of Wisconsin. This band of shales was not found in stratigraphic relation to the quartzite of the limestone of the sections already mentioned, but it occurs above a heavy white quartzite and beneath a bed of white marbleized limestone; and, from analogy with other sections, Mr. Emmons thinks it safe to assume that it occurs above the main body of quartzite and near the base of the transition series.[3]

For the purpose of comparison, a section was measured by Mr. Whitman Cross, in William's Cañon, near Manitou Springs. Of this section Mr. Emmons says:

The purely siliceous beds at the base are much thinner than in the Mosquito Range, the greatest thickness found being 50 feet. They are succeeded by calcareous sandstones and shales of variegated colors, red prevailing, which pass up into white or drab limestones, sometimes containing chert secretions and alternating with shaly beds, with an aggregate thickness of about 200 feet. These beds may be considered as the equivalents of the lower quartzite and white limestone of the Mosquito Range.[4]

[1] Geology and mining industry of Leadville, Colorado. U. S. Geol. Surv., Monograph, vol. 12, 1886, p. 60.

[2] Op. cit., pp. 58, 59. [3] Op. cit., p. 60. [4] Op. cit., p. 63.

From the east bank of Trout Creek, in Manitou Park, Mr. Cross obtained fossils from a reddish brown sandstone, 45 feet above the Archean, among which an elongate form of Lingulepis, allied to *L. pinnaformis* of the Potsdam sandstone of Wisconsin, occurs. From the red calcareous sandstones, alternating with white limestone, 105 to 122 feet above the Archean, the fauna is the type of that of the lower portion of the Lower Silurian (Ordovician).

Two sections measured on Trout Creek by Dr. A. C. Peale gave the following results:[1]

	No. 4.	No. 5.
	Feet.	*Feet.*
1. Granitic		
2. Yellow sandstone	73	65
3. Pinkish sandstone		
4. Dark, purplish brown sandstone	16	13
5. Green sandstone	4	3
6. Blood-red calcareous sandstone	54	60
7. Pink limestones		

"Beds No. 6 and 7 are fossiliferous and belong in all probability to the Quebec group, while the sandstones below are Potsdam." A list of fossils is given as coming from No. 7 which indicates a grouping of Cambrian and Silurian (Ordovician) genera unknown elsewhere.

Dr. F. M. Endlich's synopsis of the rocks of the Potsdam group found in Colorado sums up all that was known to him of the principal localities and the character and thickness of the strata. Seven localities are mentioned, as follows:[2]

			Feet.
Potsdam Group.	Lime Creek	White sandstone and quartzite	250
	Eagle River	White quartzites	300 to 400
	Four-mile Creek	Red and pink sandstones and quartzites	160
	Trout Creek	Yellow and pink sandstones	80
	North of Mount Ouray	White and pink quartzites	200
	Near Canyon City	Variegated micaceous and calcareous sandstones.	
	Glen Eyrie	Red sandstones and quartzites	40
	Average thickness of strata		180

That the Upper Cambrian zone is represented is fairly well proved by the Mosquito Range section and that of Trout Creek of the Colorado Range, and it is very probable that the sandstones correlated with the

[1] Report of A. C. Peale, M. D., Geologist of the South Park Division. U. S. Geol. Surv. of the Terr., 7th Ann. Rep., 1874, p. 208.

[2] Report of F. M. Endlich, Geologist of the White River Division. U. S. Geol. Surv. of the Terr., 10th Ann. Rep., 1878, p. 130.

Potsdam really belong within the Upper Cambrian horizon. From our present knowledge the Upper Cambrian zone is the only portion of the group represented in Colorado.

The Cambrian rocks included within the States of Colorado, Wyoming, Montana, and South Dakota are of the type of those of the southern Interior Continental, Upper Cambrian series, and consist usually of a bed of quartzite or conglomerate, resting unconformably upon the Algonkian or Archean, and passing above into calcareous beds that frequently carry the Upper Cambrian or Potsdam fauna. This is the case with the formation about the Big Horn Mountains, Wind River Mountains, and the Teton and Gros Ventre ranges of Wyoming. In some instances, however, as about the Black Hills, a fauna occurs in the basal sandstone similar in character to that of the St. Croix sandstone of the upper Mississippi Valley. Traces of a fauna were found in Colorado, at Quandary Peak, in a schistose rock that is supposed to occur just above the quartzite.

SOUTHWESTERN SUB-PROVINCE.

The widely separated areas of Cambrian rocks in Central Texas and northwestern Arizona are united in one sub-province on account of their similarity in stratigraphic position, general sedimentation, and faunas.

TEXAS.

With the exception of the doubtful occurrence of the Upper Cambrian zone as a sandstone in the Organ Mountains of southwestern Texas, as mentioned by Mr. W. P. Jenney, the Cambrian formation is, as far as known, confined to the Paleozoic uplift in the central part of the State that includes Llano County within its central portion.

A section of the formation measured by Dr. B. F. Shumard in Burnet County, 5 miles northwest of the town of Burnet, is as follows:[1]

	Feet.
No. 1.—Soft, chalky limestone with well marked cretaceous fossils	50
No. 2.—Gray and bluish gray hard limestone, of a sandy texture, in beds from a few inches to a foot thick, and containing *Arionellus* (*Bathyurus?*) *planus*, *Bathyurus depressus*, *Camerella* sp., *Orthis coloradoensis*, *Orthis* sp.?, *Discina microscopica*, and *Lingula* sp.?	81
No. 3.—Mottled gray, purple, and greenish, earthy and subcrystalline limestone, with alternating bands of siliceous limestone—contains the same fossils as No. 2	45
No. 4.—Slope with projecting ledges of No. 3	55
No. 5.—Slope	24
No. 6.—Schistose coarse textured limestone, made up of crystalline particles and abounding with fragments of trilobites, chiefly Arionellus	20
Total	275

[1] The Primordial zone of Texas, with descriptions of new fossils. Am. Jour. Sci., 2d ser., vol. 33 1862, p. 216.

A second section, taken about 1 mile south of the preceding, is also quoted, as it carries the series down to the granite: [1]

	Feet.
No. 1.—Cretaceous strata in horizontal beds	110
No. 2.—Slope, covered with conglomerate, composed of pebbles of sandstone and calciferous sandrock, rather firmly cemented	12
No. 3.—Potsdam sandstone, consisting of thin layers of variegated green, gray, and purplish sandy limestone, with bands of dolomite and silico-calcareous rock interstratified. Some of the beds are highly charged with trilobites, of which the most common are *Arionellus texanus, Dikelocephalus roemeri*, and *Conocephalites billingsi*	40
No. 4.—Highly ferruginous siliceous sandstone, composed of fine grains, loosely cemented, passing downwards into coarse gritstone and conglomerate. The upper beds contain Lingula and Obolus (?)	60
No. 5.—Flesh colored granite, interstratified with veins of milky quartz	6

From the sections it will be observed that the strata consist largely of limestone, with a bed of sandstone at the base.

The section of Packsaddle Mountain, in Llano County, in the valley of Honey Creek, is given as follows by Mr. C. D. Walcott in 1884:[2]

	Feet.
5 = Potsdam limestone	60
4 = Potsdam sandstone	30
3 = Potsdam limestone	310
2 = Massive Potsdam sandstone	205
1 = Llano group.	
	605

The fauna collected included 12 genera and 25 species, all characteristic of the Upper Cambrian zone.

A comparison of the Texas section with that of the Grand Cañon of the Colorado, in northern Arizona, leads to the conclusion that they belong to the same area of sedimentation. In each a massive sandstone at the base is subjacent to alternating sandstones and limestones that carry essentially the same fauna. The sections of the lower sandstones of the eastern slopes of the Rocky Mountains partake somewhat of this character, especially those of the Big Horn range in Wyoming. In Wisconsin, etc., the calcareous beds of the Texas section are absent, but the presence of the Dikelocephalus fauna at the summit of each series above a zone carrying what may be called the *Ptychoparia minor* fauna, proves that the life of the two areas continued on in the same succession despite the change in sedimentation and environment.

In a report on the Cambrian system Prof. T. B. Comstock concludes that at least two and probably three series of Cambrian strata are represented in central Texas.[3] To the basal beds he gives the name Hickory series (Lower Cambrian?). For the second horizon the name Riley series (Middle Cambrian?), and for the upper series the name

[1] Op. cit., p. 217.

[2] Note on Paleozoic rocks of central Texas. Am. Jour. Sci., 3d ser., vol. 28, 1884, p. 432.

[3] A preliminary report on the geology of the central mineral region of Texas. 1st Ann. Rep. Geol. Surv. of Texas for 1889-'90, pp. 285-291.

Katemcy (Potsdam) series (Upper Cambrian?). This upper series is divided into Division A, the Potsdam sandstone; Division B, the Potsdam flags; Division C, the Potsdam limestone.

ARIZONA.

As far as known the Cambrian rocks of Arizona are confined to the sections exposed by the Grand Cañon of the Colorado and along the southwestern margin of the great Colorado Cañon plateau.

A section measured near the head of the Grand Cañon has 300 feet of sandstone at the base that rests unconformably upon the subjacent Algonkian (Chuar) formation. Above the sandstone there are 700 feet of alternating sandstones, shales, and limestones throughout which fossils of the Upper Cambrian zone have been found. These include the genera Cruziana, Lingulepis, Iphidea, and Ptychoparia. At the summit of the lower sandstone a small group of fossils was found which includes the genera Olenoides, Ptychoparia, Lingulepis, and Leperditia. The upper part shows close relation to that of the Potsdam sandstone horizon of central Nevada, the Mississippi Valley, and New York, while that of the lower zone or the summit of the sandstone is more nearly related to that of the Middle Cambrian zone of the Southern Appalachians. There is a large quantity of material in the laboratory of the U. S. Geological Survey yet remaining to be studied, but I think these conclusions will not be materially changed.

At the mouth of Kanab Creek, west of the Kaibab Plateau, there are 100 feet of arenaceous and micaceous shales, subjacent to a massive stratum of mottled limestone. In the lower 450 feet of the latter and in the arenaceous shale fossils were found similar in character to those of the upper portion of the section, as seen near the head of the cañon. They include Lingulepis, Hyolithes, and Ptychoparia.

The section at the mouth of the Grand Cañon, as given by Mr. A. R. Marvine, is as follows:[1]

		Feet.
Red wall limestones.		
Tonto marble limestones.		
Tonto shales	Green	25
		75
	Snuff-colored	90
	Green	415
Tonto sandstone		80
Granite		90

Mr. Marvine says that in going southward from the mouth of the cañon the Tonto shales seem to diminish in thickness, and at Tinnakah Springs they are estimated at less than 400 feet. A few miles south of this point they were still thinner, being estimated at less than 100 feet. The Tonto sandstone, however, has increased much in thickness and forms the greater portion of the section.

[1] Report on the geology of route from St. George, Utah, to Gila River, Arizona, examined in 1871. Rep. on Geog. and Geol. Expl. and Surv. west of 100th merid., in charge of Lieut. Geo. M. Wheeler, vol. 3, Geology, 1875, p. 199.

On the atlas sheet issued by the Wheeler Survey in 1874 the Silurian (which also included the Tonto formation) is represented as extending from the head of the Grand Cañon along the entire course of the cañon to its mouth, and thence southward along the western margin of the Colorado plateau to Music Mountain, where the outcrop broadens out and extends southwest along the southwestern margin of the plateau. The most southeastern outcrop is on the Rio Verde River near the lower end of Williamtown Valley.

In all the sections on the line of the Grand Cañon and the western and southwestern margins of the Colorado Plateau the Tonto sandstone rests uncomformably upon either Algonkian or Archean rocks. In its greatest development the formation attains a thickness of 1,000 feet and represents the Upper Cambrian zone, and possibly in the lower portion, the Middle Cambrian.

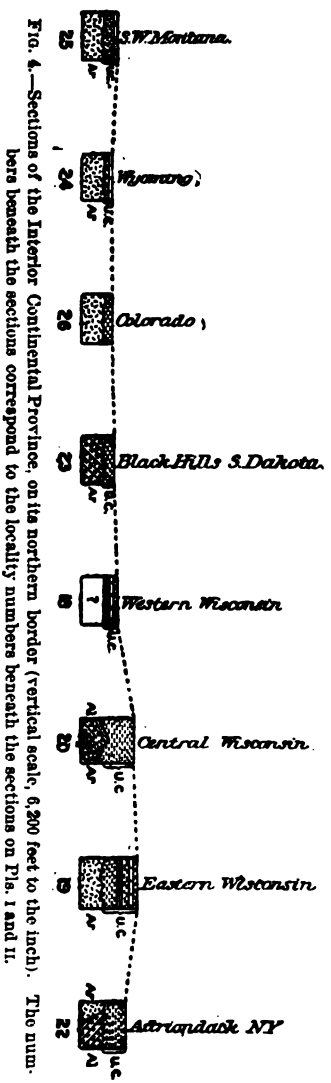


FIG. 4.—Sections of the Interior Continental Province, on its northern border (vertical scale, 6,200 feet to the inch). The numbers beneath the sections correspond to the locality numbers beneath the sections on Pls. I and II.

RÉSUMÉ.

The sediments of this province are those deposited as the sea advanced slowly upon the land and distributed the débris worn from it or brought in by tributary streams as layers of sand along the coast line and in an adjoining shallow sea. From Arizona to Texas, to Missouri, the Black Hills, and the eastern margin of the Rocky Mountains, and all along the northern line in Minnesota, Wisconsin, Michigan, Canada, and the Adirondacks of New York, the record is the same—sandstones resting upon pre-Cambrian rocks and carrying essentially the same fauna. In some regions the depth of water increased more rapidly and calcareous deposits accumulated upon the sand, as in Arizona, Texas, the Black Hills, and in some localities along the eastern base of the Rocky Mountains. That the sea was shallow, wide spread, and advancing along a great extent of coast line is shown by the sediments and the presence of a similar fauna in New York, the Upper Mississippi Valley, the Black Hills, the eastern front of the Rocky Mountains, and far to the south in Texas and Arizona. All over this broad area the rela-

tive stratigraphic succession of the sub-divisions of the Upper Cambrian fauna is the same; and nowhere do we know of the existence of formations characterized by the Lower and Middle Cambrian faunas of the Atlantic coast, Appalachian and Rocky Mountain provinces, except, perhaps, the Middle Cambrian fauna in the southwestern Interior Continental sub-Province.

In the Atlantic Coast Province the basal beds of the Olenellus zone rest unconformably upon Archean and Algonkian rocks. The sea deposited the Cambrian sediments across the upturned edges of the Laurentian and those of the superjacent bedded sandstones, quartzites, argillites, and slates forming the Algonkian series, which Dr. Murray referred to the Huronian. The upper St. John's slates carrying the Aspidella were also planed away by the Cambrian Sea. In the Interior Continental Province in Wisconsin and Minnesota the Upper Cambrian sandstones are unconformably superjacent to the corresponding series of rocks, or the Laurentian, Huronian, and Keweenawan series of the Lake Superior region. In the first instance the earlier Cambrian sea transgressed upon the pre-Cambrian rocks, and in the latter case the later or closing epoch of the Cambrian was the one in which the deposits were accumulated upon the Archean and Algonkian rocks. A misapprehension of these facts has led several geologists to refer the Keweenawan and other pre-Cambrian rocks to the Cambrian.

FIG. 5.—Sections of the Interior Continental Province, in the south central and southwestern portions.

DESCRIPTION OF PLATE I.

Geographic distribution of the Cambrian strata shown by surface outcrops in North America.

The geologic provinces are indicated by the dotted lines. The Interior Continental Province is broken up into sub-provinces and these are united by a lighter dotted line. The provinces are:

A.—Atlantic or Eastern Border Province.
- *a.* Eastern or Nova Scotia Basin.
- *b.* Southeastern Newfoundland, eastern New Brunswick, and Massachusetts Basin.
- *c.* Interior deposits of Gaspé, Quebec, Maine, New Hampshire, Vermont, and Massachusetts.

B.—Appalachian or Interior Eastern Border Province.

C.—Rocky Mountain or Western Border Province.

D.—Interior Continental Province.
- D^1. Central Interior or Upper Mississippi and Missouri.
- D^2. Eastern Interior or Adirondack of New York, and Canada.
- D^3. Western Interior or Dakota, Wyoming, etc.
- D^4. Southwestern Interior or Arizona and Texas.

The outlines of the provinces are drawn so as to include the outcrops known at present. They are arbitrarily assumed, as we do not know the exact limits of the original Cambrian sedimentation.

Owing to the uncertainty as to the Cambrian age of the outcrops of Nova Scotia, Maine, New Hampshire, and north into Canada, the indicated areas upon the map have horizontal black lines to distinguish them from the known Cambrian rocks.

SYNOPSIS OF THE CAMBRIAN GROUP.

The coordination of the Cambrian group in America, with the primary subdivisions of the Paleozoic—Silurian, Devonian, and Carboniferous—is largely a development of the past decade. Although strongly advocated by Dr. T. S. Hunt and used by Sir J. W. Dawson in 1872, and the Fortieth Parallel Survey in 1878, Le Conte's Elements of Geology of 1878 mentions, but does not use the name in classification, and Dana's Manual of 1876 classes the "Primordial or Cambrian" as the lowest formation of the Silurian.

To-day the group is firmly established by (*a*) the presence in the Rocky Mountain province of 6,000 feet of limestone with 10,000 feet or more of quartzite beneath; (*b*) in the Appalachian Province by over 12,000 feet of quartzite, shales, slates, and limestones; (*c*) a continental distribution; (*d*) a characteristic, highly differentiated fauna.

The various formations referred to the group are mentioned in the following table. In some instances it is not practicable clearly to define by name the exact limitations of the formation through which a certain division of the fauna ranges. In such cases reference will have to be made to the text for further description.

Classification of the formations.

		Lower Calciferous.	Lower portion of the Calciferous sandrock of New York and Canada; Lower Magnesian limestone of Wisconsin, Missouri, etc.
Cambrian.	Upper Cambrian.	Potsdam.	*Type.* Sandstones of the north and east sides of the Adirondacks Mountains of New York and adjoining parts of Canada. *Correlated.* Limestones of the south side of the Adirondacks and Dutchess County, New York, and an unknown portion of the limestones of the "Marble Belt" of western Vermont. Shales of Tennessee (Knox), Georgia, and Alabama (Connasauga). Sandstones of the Upper Mississippi Valley (St. Croix), South Dakota, Wyoming, Montana, and Colorado. Sandstones and calcareous beds of northern Arizona (Tonto) and central Texas (Katemcy). Limestones and shales of Nevada (Hamburg), Idaho, and Montana (Gallatin). Black shales of the upper portion of the New Brunswick and Cape Breton Island sections. Shales and sandstones of Conception Bay, Newfoundland (Belle Isle).
	Middle Cambrian.	Acadian.	*Type.* Shales and slates of eastern Massachusetts (Braintree), New Brunswick (St. John), and eastern Newfoundland (Avalon). *Correlated.* Limestones of Dutchess County, New York (Stissing), and central portions of Tennessee and Alabama sections (Coosa). Limestones of central Nevada and British Columbia (Mount Stephen).
	Lower Cambrian.	Georgian.	*Type.* Shales and limestones of western Vermont (Georgia) and Red Sandrock. *Correlated.* Quartzite of western slope of Green Mountains ("Granular Quartz") and Appalachian Range of Pennsylvania, Virginia, Tennessee (Chilhowee), Georgia, and Alabama. Shales with interbedded limestones and roofing slates of southern Vermont, New York, and south to Alabama. Limestone, sandstone, and shales of Straits of Belle Isle (Labrador), northwest coast of Newfoundland, and peninsula of Avalon (Placentia). Basal series of Hanford Brook Section, Caton's Island, etc., New Brunswick (Hanford). Shales and limestones of eastern and southeastern Massachusetts (Attleborough). Lower portion of Eureka and Highland Ranges, Nevada (Prospect). Portion of Wasatch Cambrian section (Cottonwood). Base of Castle Mountain limestone, British Columbia (Castle Mountain).

Table showing the order of succession of the Cambrian faunas in typical areas in America.

Cambrian Group.		Newfoundland.	Massachusetts.	New York.	Tennessee.	Nevada and Utah.	British Columbia.	Upper Mississippi Valley.	Texas and Arizona.
	Upper Cambrian.	Olenus zone.	Unknown.	Dikelocephalus zones.	Present.	Dikelocephalus zones.	Not recognized, but probably present.	Dikelocephalus zones	Dikelocephalus zones.
	Middle Cambrian.	Paradoxides zones.	Paradoxides zones.	Indicated by other genera than Paradoxides.	Represented by other genera than Paradoxides.	Represented by other genera than Paradoxides.	Represented by other genera than Paradoxides.	Unknown.	Not determined.
	Lower Cambrian.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Olenellus zones.	Unknown.	Unknown.

BASE OF CAMBRIAN.

The statements made in the preceding paragraphs foreshadow the conclusion that over the Interior Continental area the basal beds of the upper division of the group rest unconformably upon pre-Cambrian rocks. This is true also of the lower division of the Atlantic Coast Province, but in the Lake Champlain Valley and the Southern Appalachian Province there is no positive assurance that the conformable series of strata beneath the Olenellus zone do not pass down into some pre-Cambrian group. In Nevada, Utah, Montana, and British Columbia the same conditions exist to a more marked degree, and I have, in the absence of paleontologic proof, referred the conformable pre-Olenellus strata to an Algonkian group. That a considerable portion if not all of the series will be ultimately referred to the Cambrian is probable from the fact that the Olenellus fauna has been traced downward through 1,000 feet of limestone in the Champlain Valley of Vermont and 3,000 feet downward in the Bow River series of British Columbia. The great vertical distribution of the fauna in the limestone leads to the expectation that it will be found to range through a considerable portion of the conformable strata beneath the narrow Olenellus zone of the Southern Appalachian and southern portion of the Rocky Mountain Province. On the map of sections the lower strata are provisionally and doubtfully referred to the Cambrian. This is in opposition to the view advanced in the Tenth Annual Report of the U. S. Geological Survey.

SUMMIT OF CAMBRIAN.

The determination of the top of the Cambrian is beset with more difficulties than its delimitation at the base. At the base there are marked unconformities, and in their absence the presence of a distinctly marked fauna beneath which no other fauna has yet been found. At the summit, however, we meet with a transition both in sedimentation and fauna to the characteristic type of the Silurian (Ordovician). One of the best illustrations of this is in the Eureka district of Central Nevada, where, in the Pogonip limestone, the passage from the Cambrian to the Silurian (Ordovician) is so gradual that it is only by the predominance of the fauna of one or the other of the two great groups that a line of demarkation can be drawn. The transition is such as might be expected where there was no marked physical disturbance to influence the change of faunas resulting from the natural dying out and development of species or the influx of new species from other areas. The sedimentation was very uniform, and no essential change of character occurs between the limestones of the Upper Cambrian and those of the Silurian (Ordovician). On the other hand, the delimitation between the two groups on the northern side of the Adirondacks is clearly and definitely marked by the occurrence of a light-colored, calciferous sandrock, with its distinctive fauna, resting upon a compact, hard quartzite, characterized by the

Dikelocephalus fauna of the Upper Cambrian. Various grades of transition occur between these two extremes, but frequently it is necessary to draw an arbitrary line and define the upper limit of the Cambrian, as terminating where, in any continuous section, the Upper Cambrian fauna gives way, and is superseded by the types of the Silurian (Ordovician) fauna. In Nevada this line would be drawn near the base of the Pogonip limestone; in Tennessee, near the base of the Knox dolomite; in northern New York, north of the Adirondacks, between the Potsdam sandstone and the Calciferous sandrock; on the south side of the Adirondacks, in the limestone between the Potsdam and Calciferous faunas; in the Upper Mississippi Valley, between the upper beds of the St. Croix sandstone and the Lower Magnesian limestone, or in some instances in the lower portion of the Lower Magnesian limestone; in the series of shales opposite Quebec, at Point Levis, beneath the graptolitic-bearing shales and the conglomerate carrying the Dikelocephalus fauna of the Upper Cambrian; and in western Newfoundland, in the limestones between the Upper Cambrian fauna and the base of the Ordovician fauna.

The paleontologic break between the Cambrian and Silurian groups is practically complete where the stratigraphic break is marked. About the Adirondacks the only species I know of that cross the break are the *Lingulepis acuminata* and a species of Ophileta, at Chateaugay Chasm. In Wisconsin some of the species of the Upper Cambrian fauna apparently rise into the lower portion of the Lower Magnesian limestone, and are there associated with forms which are considered to be more typical of the Silurian (Ordovician) fauna. In Nevada, where the sedimentation is of the same character in the Upper Cambrian and the lower portion of the Silurian (Ordovician), there is a slight blending of the faunas, as shown by the occurfence of the genera Asaphus, Dikelocephalus, and Ptychoparia upon the same surface of rock. With our present knowledge, however, the occurrence of the same species in strata that are referred to the Cambrian and the Lower Silurian is so rare that they are the exceptions to the general rule.

It is not, however, by the specific break in the fauna that the two groups are separated; it is the general facies of the fauna referred to the Cambrian and that referred to the Silurian (Ordovician). The distinctness of the Upper Cambrian fauna from the Lower Silurian fauna 100 feet beneath the line of contact of the two groups is such that I think there will be no confusion between the two faunas in America. In England the range of the genus Agnostus has complicated the separateness of the two faunas, but this is not sufficient to combine them as a whole.

SEDIMENTATION OF THE CAMBRIAN GROUP.

The physical and lithologic characters of the strata lead to the conclusion that the sediments were accumulated in relatively shallow seas in the immediate vicinity of the shores of land areas that were being slowly depressed in relation to the surrounding waters. There are

some exceptions, as, for instance, the deeper water limestone series of central Nevada, British Columbia, and western Vermont, and perhaps the black shales of the Atlantic Coast Province. The assembled evidence sustains the view that at the beginning of Lower Cambrian time the area of the great Interior Province formed part of a continent, to the eastward and westward of which long ridges of pre-Cambrian rock separated interior seas and straits from the continental area and protected their contained life and sediments from the ravages of the open ocean. As the continent was slowly depressed and the waters advanced upon the land the sediments now forming the rocks of the Lower and Middle Cambrian series were accumulated in the various interior bodies of water to the eastward and westward of the main land area and between it and the outlying ridges. What the contour of the south and southeastern side of the continent was and to what extent the sea advanced upon it from the south during this time is unknown and may never be known, as only the formations that were deposited around the pre-Cambrian islands of Texas and Missouri are now accessible for study. From the evidence afforded by these two localities and that along the eastern front of the Rocky Mountains, and the exposures of Cambrian strata in Wisconsin, Canada, etc., it is very probable that the main portion of the continent north of the thirtieth and south of the fiftieth meridian did not disappear beneath the advancing sea until near the beginning of Upper Cambrian time. The unconformable position of the Upper Cambrian rocks of the Interior Continental Province upon the subjacent Algonkian and Archean rocks sustains this conclusion.

As the sea was transgressing over the surface of the continent on its way northward across the broad interior in late Middle or early Upper Cambrian time it was also working along the base of the border ridges and depositing the sediments derived from them conformably upon those deposited, while the main mass of the continent was above the water. That these deposits were practically contemporaneous with those of the Interior Province is proved by the presence of the same types of animal life, and to a considerable extent of identical species.

Toward the close of Cambrian time a large portion of the continent had disappeared beneath the surface of the sea, and the great limestone-forming period of the Silurian (Ordovician) began. In some areas, as about the Adirondack Mountains of New York, argillaceous and arenaceous sediments were derived from the adjoining coast line, but as a whole mechanical sediments are absent.[1]

[1] In speaking of the conditions of sedimentation Messrs. Campbell and Ruffner state that "Changes such as these occurred, during a series of geological ages of unknown length, in a great inland sea which was once connected with what is now the Gulf of Mexico, on the south, limited probably by the highlands of Canada on the northeast, having the Archean ledges of the Blue Ridge for its southeastern border, and in all probability separated, in part at least, from the Pacific Ocean by the Rocky Mountain Range. This extensive sea, with Archean rocks for its bottom and shores, was the receptacle of the various materials that now constitute the surface rocks and soils of the Mississippi Valley." (A physical survey extending from Atlanta, Georgia, across Alabama and Mississippi to the Mississippi River, along the line of the Georgia Pacific Railway. New York, 1883, pp. 9, 10.)

Secular disintegration had prepared an immense amount of material for the advancing sea to assort and rearrange in early Cambrian time. This, with that worn from the solid rocks by the attack upon the coast line, was largely disposed of prior to the opening of the limestone-forming period—an epoch varying in relative time in the various provinces.

I do not think it probable that any considerable amount of sediment accumulated in the southern portion of the Interior Continental area during early Cambrian time. The sections of the Champlain Valley, eastern Tennessee, Utah and Nevada, and of British Columbia prove the accumulation of from 10,000 to 12,000 feet of sediment along the eastern and western flanks of the pre-Cambrian continent before the sea deposited the formations about the Llano Hills of Texas, the Ozark Mountains of Missouri, and other portions of the Interior Continental Province. This evidence leads to the belief that the continent stood at a considerable elevation, and that the great accumulation of sediment during late Algonkian and early Cambrian time resulted from the distribution of material worn from the shore by the waves and brought into the sea by the rivers of the Interior Continental region and the outlying ridges.[1]

DESCRIPTION OF PLATE II.

Map of the central portion of the North American continent, to illustrate the relative thickness of the strata composing the Cambrian group in the various geologic provinces. (The small ring with the dot in the center indicates the geographic location of the base of the section.)

The sections are grouped into the following geologic provinces:

Atlantic Coast Province.
Appalachian Province.
Rocky Mountain Province.
Interior Continental Province.

The latter consists of the Central Interior or Upper Mississippi, the Western or Rocky Mountain, the Southwestern or Arizona and Texas, and the Eastern or Adirondack sub-provinces.

ATLANTIC COAST PROVINCE:

SECTION 1. *Conception Bay, Avalon Peninsula, Newfoundland.*—The Cambrian rocks of the Avalon Peninsula rest unconformably upon strata of Archean and Algonkian age. The section represented is formed by the union of portions of those of Manuel's Brook, Kelly's, Great Bell, and Little Bell Islands.

SECTION 2. *Vicinity of St. John, New Brunswick.*—This section is unconformably superjacent to the Archean, and unites the section at the city of St. John and that of Hanford's Brook.

[1] It is not improbable that the area of the great coastal plain of the Atlantic slope was then an elevated portion of the continent and that much of the sediment deposited during Cambrian and later Paleozoic time was washed from it into the seas immediately to the west. If this be true the source of much of the sediment of the Appalachian series of rocks is accounted for and the absence of the deposits of the eastern coast line is explained by the sinking of the coastal region during, or at the close of Paleozoic time. This view is strengthened by the presence, in the Middle Cambrian fauna of Alabama, of a number of species that are closely allied to if not identical with species of the Middle Cambrian fauna of Newfoundland and Sweden. This fauna is unknown in the Appalachian Province north of Alabama. This leads to the inference that it was distributed along the shore of the Atlantic Coast Province, and that the line of deposits, uniting the Newfoundland and Alabama areas, south of the Massachusetts area, are now buried deep beneath later deposits.

SECTION 3. *Vicinity of North Attleborough and Braintree, Massachusetts.*—In this section the Lower Cambrian series of North Attleborough and the Middle Cambrian of Braintree are united in one generalized section. The basal series is unconformably superjacent to the Archean.

APPALACHIAN PROVINCE:

SECTION 4. *North side of the Straits of Belle Isle, Labrador.*—The base rests unconformably upon the Archean.

SECTION 5. *Central western Newfoundland.*—The base rests unconformably upon the Archean, but the summit of this section is not clearly defined owing to lack of data to determine the range of the fauna.

SECTION 6. *Franklin County, Vermont.*—This represents the "Red sandrock" series, with its superjacent Georgia shales, in the township of Georgia. The base is cut off by a fault line, and the exact limitation at the summit is unknown.

SECTION 7. This represents the great shale and slate section of Washington County, New York. It is cut off at the base by a fault line and the summit is not well defined.

SECTION 8. The shore-line deposits of the Green Mountains or the "Granular Quartz," above which come limestones in which Cambrian fossils have been found. At the base it rests unconformably upon the crystalline pre-Cambrian rocks.

SECTION 9. Typical section in southern Pennsylvania, showing the "Granular Quartz" resting unconformably upon the subjacent crystalline rocks and extending above into the shale series beneath the limestones.

SECTION 10. This section is that of central Virginia, not far away from the shore line. The base rests unconformably upon the pre-Cambrian rocks, and above it passes into the base of the "valley" limestones.

SECTION 11. *Rogersville, East Tennessee.*—The base of this section is cut off by a fault line and above it passes into the Knox dolomite, the lower beds of which carry the Upper Cambrian fauna. The Chilhowee Mountain section comes beneath the Rogersville, and it is so represented in this section. An interrogation point marks the hiatus between the two sections. The data for this section are given by Mr. Bailey Willis, chief of the Appalachian division of geology, U. S. Geological Survey.

SECTION 12. The line of this section extends from Rome, Georgia, westward into Alabama. At the base it is cut off by a fault and above is delimited by the Knox dolomite. The data for it are given by Mr. C. Willard Hayes, of the Appalachian division of the U. S. Geological Survey.

SECTION 13. *Western slope of the Wasatch mountains, Utah.*—In this section the 12,000 feet of quartzite and siliceous slates are tentatively referred to the Cambrian. The fossiliferous zone is confined to the upper 250 feet.

SECTION 14. *Central eastern Nevada.*—This section represents the great quartzite series beneath the fossiliferous Cambrian limestone. The base has been concealed, and the summit has been removed by erosion.

SECTION 15. *Eureka District, Nevada.*—In this section the fossiliferous Lower Cambrian strata rests conformably upon the quartzites, which pass down some 1,500 feet before being concealed. The quartzites may correspond to the upper beds of section 14. The summit of the section passes into the superjacent Pogonip limestone of the Silurian (Ordovician).

SECTION 16. *Gallatin River near Gallatin City, Montana.*—This is essentially the same as the Mount Stephen section of British Columbia (section 17). The subjacent series of quartzites and siliceous slates are tentatively included in the Cambrian.

SECTION 17. Mount Stephen section of British Columbia, in connection with the subjacent Bow River quartzite and siliceous slates. The relations of the section are the same as those of the Eureka section (15) of central Nevada, with the addition of the Bow River quartzite and slates.

ROCKY MOUNTAIN PROVINCE:

Central Interior Continental subprovince:

SECTION 18. The western section of the central Interior Continental Province as it occurs in Minnesota.

SECTION 19. Section of the Upper Cambrian sandstones of eastern Wisconsin.

SECTION 20. Section of southern central Wisconsin, showing the unconformity between the Upper Cambrian and the subjacent Algonkian and Archean rocks. Sections 18, 19, and 20 are all of Upper Cambrian age, and pass conformably above into the superjacent Lower Silurian (Ordovician) or magnesian limestones.

SECTION 21. *Ozark Mountains, southeastern Missouri.*—The relations of the Cambrian and the Archean are the same as those in the Black Hills section (section 23).

Eastern or Adirondack subprovince:

SECTION 22. *The eastern and northern slopes of the Adirondack Mountains of New York.*—In this section the Potsdam sandstone of the Upper Cambrian rests unconformably upon and against the Archean and Algonkian rocks.

Western Interior Continental or Rocky Mountain sub-province:

SECTION 23. *Black Hills, Dakota.*—The Upper Cambrian rests unconformably upon the Archean.

SECTION 24. *Eastern section of Big Horn Mountains of Wyoming.*—It is essentially the same as that of the Black Hills (section 23).

SECTION 25. *Southern Montana.*—This section is very much like that of Wyoming and of the Black Hills.

SECTION 26. *Central Colorado.*—A section representing the sandstones that lie between the subjacent unconformable Archean or Algonkian rocks and the superjacent Lower Silurian (Ordovician).

Southwestern Interior Continental sub-province:

SECTION 27. *Grand Cañon of the Colorado, northern Arizona.*—In this section the Cambrian strata are uncomformably superjacent to rocks of Algonkian age.

SECTION 28. *Llano County, Texas.*—This section is similar to that of the Grand Cañon in having an unconformity between the Algonkian and the Cambrian and in representing nearly the same geologic horizon.

Theoretic sections at close of Cambrian time.—The data for these sections are obtained from the associated map. The enormous accumulation of sediment in the Rocky Mountain Basin on the west and the Appalachian Basin or trough on the east are shown, as well as the thin mantle of sediment over the great interior. It serves to illustrate the sedimentation indicated by the vertical columns on the map.

Our knowledge of the sediments of the eastern and western sides of the pre-Cambrian continent is considerable, but of that deposited along the southward-facing front we know nothing. From the fact, however, that the same species of fossils occur in the Lower Cambrian fauna of Labrador, Massachusetts, New York, Vermont, probably Tennessee, Nevada, and British Columbia, I think we may hypothetically assume the continuance of the Lower Cambrian beneath the deposits of the Gulf States and westward through Texas, New Mexico, and Arizona. There is no known line of Lower and Middle Cambrian sedimentation across the continent to the north of this which indicates that the fauna might have been distributed along a more northern shore.

The pre-Cambrian ridges, or protaxis of the present ranges of the northeastern side of the continent, have been outlined by Prof. J. D. Dana from the known exposures of pre-Cambrian rocks.[1] The Paradoxides fauna lived in the depression between two of the eastern ridges of the Atlantic Province in the New Brunswick area, and in the bays

[1] Areas of continental progress in North America and the influence of the condition of these areas on the work carried forward within them. Bull. Geol. Soc. Am., vol. 1, 1890, pp. 36–39.

and protected shores of the seaward slope of the western ridge, where the outer or eastern ridge was absent, as in Massachusetts and Newfoundland. The sediments that accumulated to the eastward of the New Brunswick sea form the supposed Cambrian shales and slates of Nova Scotia. The inner ridges of Maine, New Hampshire, and Massachusetts bounded long, narrow seas, in which the Cambrian faunas are not known to have penetrated. The Lower Cambrian fauna probably passed from the Atlantic along the ancient Labrador shore into the interior Appalachian sea. A few types of the Middle Cambrian fauna followed, and then the passage appears to have been closed, as none of the Upper Cambrian types of the Atlantic fauna have been found in the deposits of the interior seas.

The various views, both theoretical and hypothetical, relating to the pre-Cambrian continent are embodied on the map, Pl. III, and the section at the base of Pl. II.

DESCRIPTION OF PLATE III.

Hypothetical map of the North American Continent at the beginning of and during Lower Cambrian time.

This map is based upon the sections shown on Pl. II, and the theoretic section at the base. The position of the sections on the two maps is indicated by a circle with a corresponding number on each map.

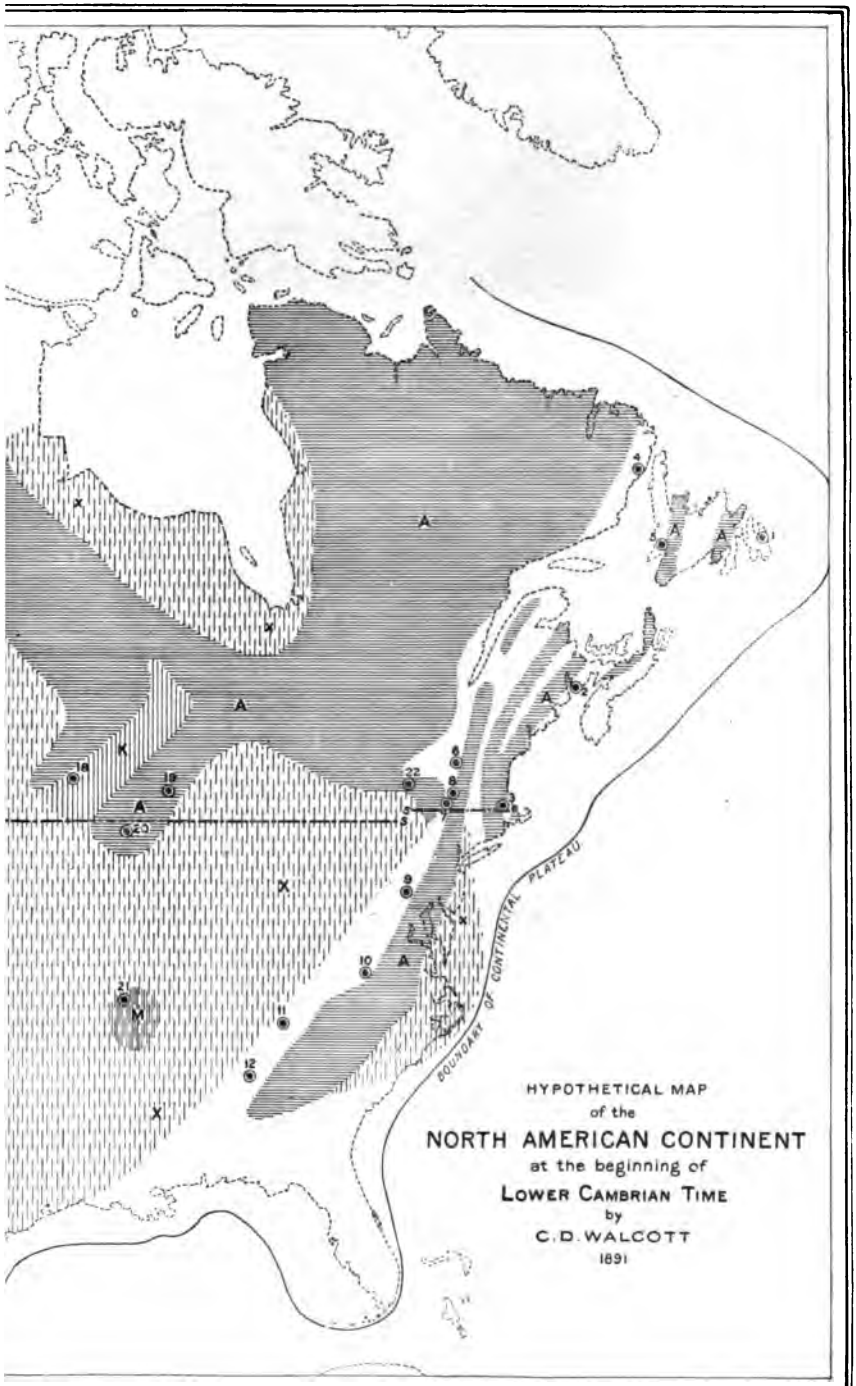
The shaded portions indicate the relative areas that are supposed to have been above the ocean during later Algonkian and Lower Cambrian time. A comparison with Pl. II shows that in the Rocky Mountain and Appalachian areas there was an enormous accumulation of sediment prior to the Upper Cambrian; while over the broad interior there is only the Upper Cambrian which corresponds to the upper portion of the great sections of the Rocky Mountain and Appalachian areas. In the region of the Atlantic Coast Province the continental movement seems to have been less, as the sediments of the Lower and Middle Cambrian are much thinner than those of the corresponding horizon in the Appalachian and Rocky Mountain areas. The conclusion is that the shaded portions and perhaps other unknown areas formed the land during late Algonkian and early Cambrian time, and that about the close of the Middle Cambrian or the beginning of Upper Cambrian time the continental surface was largely depressed beneath the waters of the ocean and the Upper Cambrian sediment accumulated over the entire area where Cambrian rocks are now known to occur. (See distribution on Pl. I.)

On Pl. III, A., Archean; K., Keweenawan; B. H., Black Hills of Dakota; T., Llano area of Texas; M., Ozark uplift of Missouri; C., Grand Cañon area of Arizona. The area marked X, X, X indicates an hypothetical land area of the existence of which we have not at present any absolute proof, as it is now covered by sediments of later age than the Cambrian.

The present shore outlines of the continent are indicated by the dotted line, and the outlines of the continental plateau on the division between the deep sea and the continent by a continuous line.

The descriptive notes of the Cambrian rocks of the various provinces and the résumé following each establishes the fact that in Cambrian time there were geographic areas in which different types of sedimenta-

BOUNDARY OF CONTINENTAL PLATEAU
A
A
A
A
X
C
C
C
16
15
15
14
25
25
25
23
23
S. H


BOUNDARY OF CONTINENTAL PLATEAU
HYPOTHETICAL MAP
of the
NORTH AMERICAN CONTINENT
at the beginning of
LOWER CAMBRIAN TIME
by
C. D. WALCOTT
1891
600 STAT MILES

tion prevailed, and that great variation existed in what are considered the same geographic provinces. The sediments of the northeastern Atlantic Coast Province are almost entirely shales with a small proportion of sandstone and a trace of limestone. Tracing the long Appalachian Province from the Gulf of St. Lawrence to the southwest and south, we find an immense accumulation of shale with some interbedded sandstone and limestone. This extends to the Lake Champlain region of New York and Vermont, where a great limestone of Lower Cambrian age is subjacent to several thousand feet of shale in which lenticular masses of sandstone and limestone occur at irregular intervals. Farther to the southwest, in southern Vermont and eastern New York, great thicknesses of argillaceous sediment were deposited. These now form the series of shales in which beds of finely laminated roofing slates occur in massive strata. Toward the east, near the pre-Cambrian shore line, the Lower Cambrian sandstones are followed by arenaceous, dolomitic, and purely calcareous limestones of later Cambrian time. This condition of sedimentation continues far to the south, varied more or less by the presence of great thicknesses of shale above the lower quartzite. In the latter case the limestone of the Cambrian forms only a thin belt at the summit.

In the Rocky Mountain Province the siliceous sediments, sandstones, and quartzites are followed by limestone, and nearer the shore line, the sandstones are subjacent to shale. Over the Interior Province the record is sandstone, followed on the west and southwest by alternating limestones and sandstones.

On the map (Pl. II) the thickness and character of the sediment is shown in a general manner for each of the provinces.

The study of the fauna has shown that, while there is a general resemblance in the faunas of the Lower Cambrian in the Atlantic Coast, Appalachian, and Rocky Mountain Provinces, there is sufficient differentiation to mark off distinct faunal areas in the early Cambrian sea.

The fauna of the Upper Cambrian is less specialized over great areas than that of the Lower and Middle zones. The opportunities for communication between the provinces were greater and it is only in the Northeastern or the Atlantic Coast Province that a marked difference is shown.

The Middle Cambrian fauna of the Atlantic Coast Province is so strongly differentiated from that of the Appalachian and Western Rocky Mountain Provinces that it was not until they were found to occupy the same relative stratigraphic position that it was suspected they lived in approximately the same epoch.

The evidence of sedimentation and the evidence of organic remains unite to prove that in Cambrian time the geographic and faunal provinces were differentiated and established over the area of the present North American continent. In fact, the sedimentation of the Cambrian was as varied as that of many of later geologic periods and more so than that of the immediately succeeding Silurian (Ordovician).

SUBDIVISION OF THE CAMBRIAN.

In his admirable report upon the Devonian of North America Prof. H. S. Williams expresses this opinion:

> The subdivision of any great geological system must depend in great measure upon the differences in the faunas or floras contained, and, as I believe, this depends in no small degree upon the geological changes which modified and shifted the geographical conditions under which the animals lived. A sandstone will not contain the same species as a following limestone, and even in arenaceous shales a slight change in the fineness or coarseness or in the amount of argillaceous mud mixed with the sand modifies the composition of the fauna contained in it.[1]

There are not at present sufficient available data from the Cambrian upon which to base comparisons with the same degree of refinement as those made by Prof. Williams. It has been discovered, however, that the predominant types of life of the Cambrian group are to be found in shales, limestones, and sandstones. For instance, the genus Olenellus, characteristic of the Lower Cambrian, is found in the shales, limestones, slates, and sandy shales of the typical section in Northern Vermont. I have found in the quartzites and in the pure limestones of the Potsdam epoch of the Adirondack subprovince the same species of Dikelocephalus, Hyolithes, and Lingulepis. In the dark argillaceous shales of the Middle Cambrian terrane of Newfoundland I found the same species of Paradoxides that occurs in the interbedded limestones of the same series a few miles distant. That Prof. Williams is correct in relation to the great mass of organisms that existed during Paleozoic time there can be very little if any question. As an example the corals of the limestones of the north shore of the Strait of Belle Isle, on the Labrador coast, are unknown, except in an almost identical limestone at Silver Peak, Nevada, in the Rocky Mountain Province. It is in the clearer limestones that the great bulk of the brachiopods, pteropods, and other forms of life are found in the Cambrian; but it is a fact, nevertheless, that the predominant types of the Trilobita, characterizing its three divisions, flourished upon and were imbedded in sediments of widely different character. It is owing to this that they become of so much importance as criteria in the correlation of the three primary divisions of the group.

In the Atlantic Coast Province the fauna of the Lower Cambrian, or Olenellus zone, occurs in arenaceous limestones, pure limestones, and shales. All of these are of a different character from those of the black shales 200 feet above, in which the Paradoxides or Middle Cambrian fauna occurs. The Upper Cambrian fauna is found in dark shales and sandstones several hundred feet, if not a thousand feet, above the Paradoxides zone. The three primary subdivisions of the Cambrian are strongly defined by the sedimentation and faunas. In the St. Lawrence

[1] International Congress of Geologists, American Committee. Report of the subcommittee to the session of the Congress held in London, September 17, 1888. Philadelphia, 1888. Report of the subcommittee on the Upper Paleozoic (Devonic), H. S. Williams, Reporter, p. C 20.

Valley area of the Northern Appalachian Province the Lower Cambrian and Upper Cambrian faunas are found in separate bands of conglomerate limestones and not in situ, the great thickness of shales and sandstones referred to the Cambrian not being characterized by any known fauna. In Vermont the Lower Cambrian fauna occurs throughout the classical "Red sandrock" series and the lower portion of the superjacent Georgia shales, while about 2,000 feet above, the Upper Cambrian fauna is well determined. The Middle Cambrian fauna has not been recognized. In the eastern New York section the Lower Cambrian fauna is strongly differentiated and the base of the Middle Cambrian fauna indicated; but the Upper Cambrian fauna is unknown. Only a few miles distant to the west, however, at the base of the Adirondacks, the Upper Cambrian fauna characterizes sandstones and limestones that occur beneath the base of the Silurian (Ordovician). Farther to the south, in Dutchess County, in the valley of the Hudson, the Lower Cambrian fauna is recognized in the basal quartzite and the superjacent limestone, and also the Middle Cambrian of the Appalachian and Rocky Mountain Provinces, and the Upper Cambrian of all but the Atlantic Coast Province. In Tennessee, in the Southern Appalachian Province, the Lower Cambrian fauna is found in shales, within the quartzite series, and at the summit of the shales the Upper Cambrian fauna occurs. This extends up and into the base of the limestone. In Alabama, in shales apparently occupying the same serial relation, the Middle Cambrian fauna is well developed.

In the Nevada section the Lower Cambrian or Olenellus zone is distinctly defined, and between it and the Upper Cambrian fauna 1,000 feet of limestone is marked by types of the Middle Cambrian fauna. These distinctions of faunas are readily determined wherever two or more of them are present in the same section in the Rocky Mountain Province. In British Columbia the Lower Cambrian and Middle Cambrian faunas have alone been recognized.

I have spoken of the Middle Cambrian fauna of the Atlantic Coast Province and that of the Middle Cambrian of the Appalachian and Rocky Mountain Provinces. This distinction is made because the characteristic types of the Atlantic Coast Middle Cambrian fauna are not found in the Middle Cambrian fauna of the other two provinces. This indicates that a nearly impassable barrier existed during Middle Cambrian time between the sea of the Atlantic Coast Province and those of the interior. This prevented nearly all the species of the former from migrating into the Appalachian and Rocky Mountain Provinces. Within the two latter there is a fauna characterized by similar types in New York, Alabama, Nevada, and British Columbia, and in each section where their stratigraphic position is determined they occupy the same relations to the Lower and Upper Cambrian faunas as does the Middle Cambrian or Paradoxides fauna of the Atlantic Coast Province.

The Lower Cambrian fauna is much more persistent in its character than that of the Middle Cambrian; for all the strata referred to the former horizon have been found to be characterized by essentially the same fauna. This is also true of the much more widely spread Upper Cambrian with the single exception of the Atlantic Coast Province, where the fauna is more of the European or Atlantic Basin type. There is, however, too little known of it at present in Newfoundland to base any final conclusions upon it.

The minor or formation subdivisions of the Cambrian are based largely upon lithologic characters and are relatively of local value only. One exception to this is found in the "Granular Quartz" of New York and Vermont, and the equivalent Chilhowee quartzite series of Tennessee, Alabama, Virginia, Pennsylvania, etc. Another is in the widely spread shore-line deposits, called the Potsdam sandstone in New York, the St. Croix sandstone in the Upper Mississippi Valley, the supposed equivalent deposits of the Black Hills of Dakota, the sandstones of the eastern flanks of the Rocky Mountains and of the Llano area of Texas. These two formations furnish illustrations of the accumulation of similar sediments over very extended areas. Their minor value in classification, when not supported by paleontologic evidence, is shown by the fact that the Lower Cambrian "Granular Quartz" or Chilhowee sandstone has been correlated by nearly all geologists who have referred to it with the Potsdam sandstone about the Adirondacks of New York and the St. Croix sandstone of the Upper Mississippi Valley, thus bringing together formations separated in the stratigraphic column by a long time interval and several thousand feet of sediment. Other sandstones of pre-Cambrian and post-Cambrian age have also been correlated with the Potsdam sandstone of New York.

With our present knowledge of the faunas and sediments it is impossible in all instances to differentiate the primary divisions of Upper, Middle, and Lower Cambrian in America.

Extending our views across to the eastern side of the Atlantic Ocean, we find an extensive development of Cambrian rocks in North and South Wales, where the three great divisions of the North American Cambrian are to be recognized. The Lower, in the roofing-slate series of North Wales and the Cærfai group of South Wales; the Middle, in the Solva and Menevian formations, and the Upper, in the Lingula flags series. These divisions are also recognized in Sweden and North Wales, although in greatly diminished force. The Lower division has been recognized in western Russia, and the central belt of the celebrated "Zone Primordiale" of Bohemia represents the Middle Cambrian series.

In lithologic, stratigraphic, and paleontologic characters the Cambrian series on the opposite sides of the Atlantic are such that there is no hesitancy in considering them as belonging to one geologic group and as part of one geologic basin.

There is a great variation in the sedimentation and faunas of the

various formations referred to the Cambrian in North America and Europe; they all fall within the limits of the group and, united, constitute a great geologic division of equal taxonomic value with Silurian (Ordovician), Silurian, Devonian, etc.

COMPARISON WITH THE CAMBRIAN ROCKS OF OTHER COUNTRIES.

EUROPE.

Dr. Henry Hicks expresses the view that the sediments of the Cambrian and Silurian were largely deposited on the western side of the European continent.[1] In Spain and Wales the sediments accumulated to a great thickness, while to the eastward, in Bohemia, Scandinavia, and Russia, the sections show less than one-fifth of the thickness of those in Wales. In central Russia the Cambrian strata entirely disappear and the Silurian (Ordovician) rests unconformably and directly upon the Archean. These observations lead to the conclusions (*a*) that the Cambrian sediments were deposited upon a gradually sinking coast line; (*b*) that the greatest depression was on the western margin of the continent; (*c*) that the movement which depressed the North American continent during pre-Cambrian time also affected the western side of the European continent, with a gradually diminishing force, from the Atlantic coast to the Ural Mountains.[2]

A comparison of the Atlantic Coast Cambrian series of America with the Atlantic Coast series of Europe, as exhibited in Wales, shows a marked similarity between the sedimentation of the opposite sides of the Atlantic. The basal Cambrian in South Wales, named the Caerfai group, by Dr. Henry Hicks, consists of 1,570 feet of strata, as follows: 520 feet of conglomerates and greenish sandstones subjacent to a bed of red shales and schists, 50 feet in thickness, above which 1,000 feet of purple sandstones occur. Dr. Hicks correlates the roofing slates of North Wales as found at Llanberris, Bethesda, and Penrhyn with this lower division of the Cambrian, on stratigraphic evidence, as the few fossils found are not sufficiently characteristic to correlate the two series with each other or with the American Lower Cambrian. A comparison of the sections with that of the southeastern coast of Newfoundland shows in each the presence of a basal conglomerate subjacent to a series of purple and green shales or slates. It is also to be noted that the Lower Cambrian of New Brunswick and eastern Massachusetts is made up of shales of a somewhat similar character to those of the Caerfai group. It is a curious coincidence that the section of the Lower Cambrian of North Wales is almost identical in the physical character of its slates, including color and texture, to the Lower Cambrian roofing slate belt of southern Vermont and eastern New York.

[1] On the deposition of the Cambrian and Lower Silurian rocks. Quart. Jour. Geol. Soc., London, vol. 31, 1875, Pl. 27, op. p. 558.

[2] Walcott, C. D.: The fauna of the Lower Cambrian or Olenellus zone. 10th Ann. Rep, U. S. Geol. Surv., 1890, pp. 563, 564.

The Solva group of South Wales consists of 150 feet of yellowish grits beneath 1,500 feet of gray, purple, and red rocks, above which 150 feet of gray rocks occur. All three divisions are characterized by the presence of the genus Paradoxides. The superior division of the Menevian group consists of 750 feet of slates and sandstones, and, with the Solva formation, constitutes the Paradoxides zone corresponding to the Middle Cambrian of the American section. This division is represented in Massachusetts by the Paradoxides beds of Braintree, in New Brunswick by the Paradoxides shales of the St. John Basin, and in Newfoundland by the Paradoxides shales of the Avalon Peninsula. The faunas of this division are largely identical on the opposite sides of the Atlantic, and form the great connecting link that binds the sections together and permits of almost positive correlation between them.

The North American Upper Cambrian is represented in Wales by the Lingula flags and Lower Tremadoc series, formed of over 5,500 feet of bluish and black slates and flags with bands of gray flags and sandstones. The faunal and stratigraphic equivalent of this series has been distinctly recognized in New Brunswick, on Cape Breton Island, and on the Avalon Peninsula of Newfoundland.

Most English geologists have included the Tremadoc slates in the Cambrian; but from an examination of the list of their contained fauna it appears to me that the line of demarcation between the Cambrian and Silurian, if based upon the general facies of the fauna, should be drawn in the Tremadoc series between the upper and lower divisions. The fauna of the lower division is essentially that of the Cambrian, with a few genera and species more characteristic of the Lower Silurian (Ordovician), while the fauna of the upper division is largely of the Lower Silurian (Ordovician) type, with a few forms of the Cambrian intermingled with it.

The problem of the line of demarcation between the two groups in England is essentially of the same character as that presented in Nevada, where there is no clearly drawn stratigraphic or faunal break in the Pogonip series of limestones.

That there is a strongly marked resemblance between the Cambrian series of the Atlantic Coast Province of America and that of the western Atlantic Coast Province of Wales there is no question. We are able to compare the three main subdivisions and assume that they belong practically to one province. In fact, there is no more difference between the faunas and sediments on the opposite side of the Atlantic than there is in different portions of the Appalachian Province, and not as much as between different provinces on the North American Continent.

In explaining the strong similarity of the faunas and sediments of the Cambrian rocks of the opposite side of the Atlantic, Dr. Henry Hicks says:

The home of the earliest forms of life seems to have been somewhere towards the southwest, and possibly not far from the equator; and it is from here that the various forms seem to have migrated to the areas in which they were subsequently entombed. The migrations seem to have taken place towards the North American continent very much about the same time as towards the European; and the sea encroachments along that continent seem to have been in a direction from southeast to northwest, so that the line indicating the two depressions would meet in mid-Atlantic. This accounts for the great similarity in the two faunas and for the general resemblance offered by the order of succession of these early rocks in the two continents. The higher lands in America would be to the west and northwest, and the higher lands in Europe to the east and northeast, so that the last lands submerged would approach each other and occupy the same region of the globe.[1]

The Scandinavian Cambrian series is not over 200 feet in thickness, and represents the entire British series.[2] It is divisible into the Lower Cambrian or Olenellus zone, the Middle Cambrian or Paradoxides zone, and the Upper Cambrian or Olenus zone.

On the opposite side of the Baltic, in eastern Estoria, the Lower Cambrian zone alone is recognized by the presence of its characteristic fauna. The Middle and Upper Cambrian faunas probably existed in this region, but they have not as yet been discovered.

Beneath the Paradoxides zone of central Bohemia there is a considerable thickness of shales, grits, schists, conglomerates, and quartzites that may represent the Lower Cambrian. The Upper Cambrian, if it has not been removed by pre-Silurian erosion, does not appear to have been clearly differentiated from the Middle Cambrian or Paradoxides zone.[3]

The Cambrian rocks of the north of France are correlated with the Cambrian of St. David's, Wales, by authors, but they are not sufficiently well defined by faunas to compare them with American formations. In the province of Hérault, in the south of France, the presence of Paradoxides correlates the rocks with the Cambrian of Bohemia.[4]

On the island of Sardinia there is a mixture of Middle and Lower Cambrian faunas, which may arise from the confused state of the strata, or it is not impossible that the faunas are really mingled in the same beds. In the absence of more definite data it is not practicable to compare them with the American sections.

The contrast between the American and European Cambrian, with the exception of the sections of Bohemia and Sardinia, are not as great as those between the Atlantic Coast Province and the Appalachian Province, or as between the Atlantic Coast and Rocky Mountain Prov-

[1] On the deposition of the Cambrian and Lower Silurian rocks. Quart. Jour. Geol. Soc., London, vol. 31, 1875, p. 555.

[2] See Prof. Charles Lapworth's comparative table of the Cambrian rocks of Britain and Scandinavia. "Materials for the Correlation of the Lower Paleozoic Rocks of Britain and Scandinavia." Geol. Mag., new series, dec. II, vol. 8, 1881, pp. 320, 321.

[3] Mr. J. E. Marr correlates the basal beds of Barrande's Étage D (d 1a) in which *Lingula feistmanteli* occurs in abundance, with the Lingula flags of Britain. Quart. Jour. Geol. Soc., London, vol. 36, 1880, p. 602.

[4] Bergeron, Jules: Note sur la présence de la Faune primordiale (Paradoxidien) dans les environs de Ferrals-les-Montagnes. Bull. Soc. géol. France, 3e sér., vol. 16, 1888, pp. 282–285.

inces. In point of fact the Atlantic Coast Province of America is practically a portion of the Atlantic Province of which the sections of western Europe are on the eastern side. The Bohemian area and that represented by the deposits on the island of Sardinia partake, in part, of the character of the Atlantic Basin deposits, in the presence of the Paradoxides fauna, but not in other details.

The essential difference between the English and the American classification is in drawing the line between the Cambrian and Silurian (Ordovician). The English geologists have included the Upper Tremadoc slates, with their strongly marked Ordovician fauna, in the Cambrian, because a local stratigraphic break occurs at their summit and between it and the subjacent Arenig series. By the definition adopted in this paper for distinguishing the great geologic groups, the Upper Tremadoc slates, with their fauna, would be included in the Silurian (Ordovician), and the line of delimitation between the Cambrian and the Silurian (Ordovician) be drawn at the base of the upper Tremadoc slates, thus referring the Lower Tremadoc and the Lingula flag series to the Upper Cambrian, and the Upper Tremadoc to the base of Silurian (Ordovician).

In conclusion: (*a*) The relations between the Cambrian rocks of the eastern or Atlantic coast of North America and those of Wales are of a genetic character, and point to their having been deposited in the same time interval; (*b*) the Scandinavian Cambrian represents the same interval, but with a greatly diminished bulk of sediments; (*c*) the French and Spanish sections are too incomplete for close comparison, although representing the coast of Wales series; (*d*) the Bohemian and Sardinian areas point to local conditions that may have affected their connection with the typical Atlantic Basin sediments and faunas.

SCOTLAND.

The occurrence of Cambrian rocks in Scotland has not yet been fully proved, but it is quite probable that the Torridon sandstones of northwestern Scotland may be referred to the Lower Cambrian. Prof. Archibald Geikie, in summing up the notice of the Cambrian rocks in Scotland in his Text Book of Geology, says:

> In the northwest of Scotland a mass of reddish brown and chocolate-colored sandstone and conglomerate (at least 4,000 feet thick in the Loch Torridon district) lies unconformably upon the Archean gneiss in nearly horizontal or gently inclined beds. * * * The denudation must have been considerable even in early Silurian times, for the sandstones are unconformably overlaid by quartzites and limestones containing Lower Silurian fossils, and these younger strata even in the same district rest directly on the Archean gneiss. * * * No trace of organic remains of any kind has been found in the red sandstones themselves, unless certain track-like impressions, observed on the west side of Loch Maree, can be regarded as having been imprinted by crustacea or other organisms.[1]

[1] Text Book of Geology, 1885, p. 653.

IRELAND.

The supposed representative of the Welch Cambrian series in the southeast of Ireland is described by Prof. Geikie as follows:

In the southeast of Ireland, masses of purplish, red, and green shales, slates, grits, quartzites, and schists occupy a considerable area and attain a depth of 14,000 feet without revealing their base, while their top is covered by unconformable formations (Lower Silurian and Lower Carboniferous). They have yielded *Oldhamia*, also numerous burrows and trails of annelides (*Histioderma hibernicum*, *Arenicolites didymus*, *A. sparsus*, *Haughtonia pœcila*.) No Upper Cambrian forms have been met with in the Irish rocks, which are therefore placed with the Lower Cambrian, the unconformability at their top being regarded as equivalent to the interval required for the deposition of the intervening formations up to the time of the Llandeilo rocks, as in the northwest of Scotland.[1]

A very full description of the Cambrian rocks of Ireland, especially as they occur at Bray Head, Wicklow, is given by Prof. William Hellier Baily in 1865. A diagrammatic section accompanies the paper, and the author also describes the supposed organic remains that have been found in the rocks.[2]

CHINA.

Our knowledge of the Cambrian rocks of China results from the investigations of Baron Richthofen in the province of Liau-tung in northeastern China, near the Corean frontier. He found a series of limestone containing the "Primordial" fauna in the sections of Sai-maki and Tai-tsze-ho.[3] The limestones are superjacent to a series of sandstones and quartzites that correspond in stratigraphic position to the Lower Cambrian of North America.

The collections of fossils were studied by Dr. Wilhelm Dames, who came to the conclusion that two horizons were represented—the Andrarum limestone or Paradoxides horizon of Sweden, and the Quebec horizon of North America.[4] At the time Dr. Dames wrote *Dikelocephalus gothicus* and *D. quadriceps*, which he referred to the genus Doropyge, were cited as from the Quebec group; and it was on the comparison between the *Doropyge richthofeni* and these two species that he considered that the Quebec horizon was represented. The two species mentioned are now referred to the genus Olenoides of the Middle Cambrian fauna, which is not known to occur in the Upper Cambrian or in the Calciferous-Chazy fauna corresponding to the Quebec. A study of the species illustrated by Dr. Dames leads me to think that the Middle Cambrian fauna only is present, although it is not impossible that some Upper Cambrian species may have been collected. The sections of Baron Richthofen, however, indicate a considerable thickness of con-

[1] Text Book of Geology, 1885, p. 654.

[2] The Cambrian rocks of the British Islands, with especial reference to the occurrence of this formation and its fossils in Ireland. Geological Magazine, vol. 2, 1865, pp. 385 400.

[3] Richthofen, F. F. von: China. Ergebnisse eigener Reisen und darauf gegründeter Studien. Vol. 2 (das nordliche China) fig. 21, p. 94; fig. 29, p 101, 1882.

[4] Cambrische Trilobiten von Liau-tung. China; by F. F. von Richthofen, vol. 4, 1883, p. 33.

formable strata beneath the Middle Cambrian zone in which the Lower Cambrian or Olenellus fauna should be sought for, and there are beds above in which the Upper Cambrian fauna may possibly be discovered. The geologic section is to be compared to that of the Rocky Mountain Province, and the presence of the same peculiar Middle Cambrian fauna, unmarked by the genus Paradoxides, also strengthens the comparison.

INDIA.

In a note on the discovery of trilobites by Dr. H. Warth in the Neobolus beds of the Salt Range, by Mr. Will King, director of the Geological Survey of India,[1] it is stated that the trilobites were discovered in the Neobolus beds of the Salt Range. The stratigraphic succession, from the summit downward, beneath the Carboniferous limestone, is as follows:[2]

Magnesian sandstone group.
7. Red shaly zone (Salt-pseudomorph zone).
6. Magnesian sandstone.
5. Dark shaly zone (Neobolus beds).

Purple sandstone group.
4. Upper purple sandstone (purple sandstone).
3. Rock salt and red gypsum group.
2. Gray gypsum group.
1. Lower purple sandstone.

There had been previously discovered in the Neobolus beds by Dr. Warth and Dr. Waagen a number of brachiopods, which were described by Dr. Waagen as follows: *Discinolepis granulata* (p. 750), *Schizopholis rugosa* (p. 753), *Neobolus warthi* (p. 758), *N. wynnei* (p. 759), *Davidsonella linguloides* (p. 764), *D. squama* (p. 766), *Lingula kiurensis* (p. 768) and *L. warthi* (p. 769).[3]

It is stated that the trilobites were sent to Dr. Waagen, who identified one of the two determinable species as a Conocephalites, very nearly related to *Conocephalites formosus* Hartt, from the St. John group, and the other as probably an Olenus.

The beds in which such forms occur can not be anything but Cambrian, and they must probably be classed as referable to the upper region of the Lower Cambrian.[4]

In the table the probable equivalent elsewhere of this formation is the Sinic formation of Richthofen, in China.[5]

AUSTRALIA.

The Cambrian rocks of Australia appear to be confined to the southeastern portion of South Australia and the northern portion of Tasmania. In the "Papers and Proceedings of the Royal Society of Tasmania for 1882," Mr. R. Etheridge, jr., described a species of Conocephalites which he named *Conocephalites? stephensi* (p. 153), and the tail of a trilobite which is named *Dikelocephalus tasmanicus* (p. 155).

[1] Records of the Geological Survey of India, vol. 22, 1889, pp. 153–157.
[2] Op. cit., p. 157.
[3] Memoirs of Geol. Surv., India. Palæontologia Indica, ser. xiii, vol. 1, 1887, pp. 750–770.
[4] Records of the Geological Survey of India, vol. 22, 1889, p. 154.
[5] Op. cit., p. 157.

Another pygidium is identified as belonging to the genus Asaphus, and small univalves which have the appearance of the genus Ophileta, of Vanuxem.[1]

The trilobites and the gasteropods are correlated with the Upper Cambrian fauna of America and Great Britain, to the Potsdam sandstone in America and the Lingula flags of Wales.

In 1884 Dr. Henry Woodward described some trilobites from the Parara limestone of the Yorke Peninsula, South Australia, *Conocephalites australis* and *Dolichometopus tatei*.[2] He concludes that the trilobites are clearly of Lower Silurian age, being equivalent to the Swedish, Bohemian, Tasmanian, and North American beds with similar fossils.

A recent paper by Mr. R. Etheridge, jr., on some Australian species of the family Archæocyathinæ describes the presence of several species of that family in association with trilobitic remains at Ardrassan, Yorke Peninsula, South Australia. The species described are *Ethmophyllum hindei*, *Protopharetra ? scoulari* and *Coscinocyathus tatei*.[3]

The strata containing the fossils are correlated with the Potsdam horizon sandstone of America or the Lingula flags of Wales. From the stratigraphic position of the American forms of Ethmophyllum and Coscinocyathus it is quite probable that the Australian species belong to the Lower Cambrian fauna and not to the Upper, as identified by Mr. Etheridge.

SOUTH AMERICA.

In 1876 Dr. Emanuel Kayser described a small collection of Primordial fossils made in the northern portion of the Argentine Republic, in the provinces of Salta and Jujuy, by Prof. Lorentz and Dr. Hyeronimus, of Cordova. The fossils occur in a micaceous sandstone, and include the genera Lingula, Obolus, Orthis, Hyolithes, Arionellus, Agnostus and Olenus.[4] Dr. Kayser compares the fauna with that of the north of Europe and North America, and concludes that it belongs to the upper zone of the Primordial. He calls attention to the fact that the genus Paradoxides is wanting and that Olenus appears in great numbers. "This fact seems to indicate that our fauna belongs to the upper Primordial zone or the Olenus stage."[5]

A glance at Pl. I, of Dr. Kayser's memoir proves that he is correct in the reference and that the fauna is of the type of the Upper Cambrian. From the geographical position and character of the fauna it is quite probable that Cambrian formations will be found on the eastern slope of the Andes, as well as the Cordillera of Central America and Mexico, if not concealed by later deposits.

---

[1] Papers and Proc. Royal Soc. Tasmania for 1882, 1883, pp. 151–158.

[2] Note on the remains of trilobites from South Australia. Geol. Mag., new series, dec. III, vol. 1, 1884, pp. 342–344.

[3] On some Australian species of the family Archæocyathinæ. Trans. Roy. Soc. South Australia, vol. 13, 1890, pp. 10–22, Pls. II and III.

[4] Beiträge zur Geologie und Palaeontologie der Argentinischen Republik; II. Palaeontologische Theil.; von Dr. Emanuel Kayser, Cassel, 1876, pp. 28.

[5] Op. cit., p. 29.

CHAPTER V.

PROBLEMS FOR INVESTIGATION AND SETTLEMENT.

I.—Local problems within the subdivision of each province.
II.—Problems affecting our knowledge of the Cambrian group as a whole or in large parts.
III.—Problems of nomenclature and classification.

LOCAL PROBLEMS.

There are many local problems that are not mentioned in the following notes. With the settlement of the more important questions they will assume prominence, and some of them may prove to be equal to if not of more import than those now suggested for investigation.

Newfoundland.—The prominent questions are:

(1) The determination of the relation of the Cambrian rocks of St. Mary's and Trinity Bays to the basal conglomerate in the Manuel's Brook section, to ascertain if a series of Cambrian strata occurs between the lowest recognized Cambrian on Conception Bay and Manuel's Brook and the pre-Cambrian rocks of Trinity and St. Mary's Bay, as thought by the Newfoundland geologists. If such a series be found its fauna should be carefully collected and studied with reference to its being basal Cambrian or pre-Cambrian.

(2) The discovery of an unbroken stratigraphic section to prove the assumed relations of the Paradoxides fauna to the Upper Cambrian fauna. This will probably be found in the vicinity of or on the shores of the peninsula west of St. Mary's Bay and the shores of Placentia Bay.

(3) The determination on the west and northwest sides of the island of the relations of the Olenellus bearing strata to the subjacent and superjacent beds and the character of the section from its base to the limestone carrying the Calciferous fauna of the Silurian (Ordovician).

(4) The study of the geographic distribution and detailed sections of the strata on the southwestern and northeastern coasts.

(5) The relations of the Cambrian strata to the superjacent beds of the Silurian (Ordovician) wherever they can be found in the same section.

Nova Scotia.—The important question in Nova Scotia, as in Maine and New Hampshire, is the determination of the geological age of the slates referred provisionally to the Cambrian. After this come the local details of the sedimentation and paleontology of the Cambrian terrane. Until the first is decided very little except conjecture can be used in the correlation of the slates with the Cambrian or other groups.

New Brunswick.—Through the efforts of Mr. G. F. Matthew many of the problems relating to the Cambrian system in New Brunswick have been successfully solved. More information is needed for—

(1) The clearer identification of the Lower Cambrian or Olenellus zone and its exact stratigraphic relations to the Paradoxides zone.

(2) A clearer determination of the Upper Cambrian fauna and its relations to the Paradoxides zone.

(3) It is desirable that more data should be obtained upon the zoologic relations of the different faunas to each other.

Maine and New Hampshire.—The problem presented in Maine and New Hampshire is essentially of the same character as that presented in Nova Scotia. It is the determination of the presence of rocks of Cambrian age by paleontologic evidence. Until this is done the other problems of stratigraphic succession and geographic distribution of the strata and faunas can not be considered.

Eastern Massachusetts.—In eastern Massachusetts it is desirable to ascertain—

(1) The stratigraphic relations of the strata carrying the Olenellus fauna and Paradoxides fauna and decide whether the Upper Cambrian is represented in the region.

(2) To obtain more paleontologic data in order to correlate the various outcrops that have been referred to the Lower and Middle Cambrian in different portions of the Boston Basin and to the south-southwest toward the Rhode Island line.

(3) To identify and map the Cambrian rocks in detail.

New York.—In New York it is desirable to ascertain—

(1) The exact relation of the strata carrying the Olenellus fauna to those carrying the Upper Cambrian or Potsdam fauna about the Adirondacks.

(2) The stratigraphic succession and thickness of the strata carrying the Olenellus fauna in Rensselaer and Washington Counties, and whether the Middle and Upper Cambrian can be recognized either by the faunal or lithologic characters.

(3) The geographic distribution of the Cambrian rocks in the Hudson Valley south of Rensselaer County.

Adirondack subprovince.—The most important problem in connection with this subprovince is the tracing of the transition from the sandstone of the Potsdam about the Adirondacks to the off-shore deposit represented by the shales and slates now found beneath the limestone of the marble belt of western Vermont and eastern New York. More extensive collections of fossils are also desirable for the purpose of instituting closer correlations between the faunal zones of the typical Potsdam section of the Adirondacks with that of the correlated sandstone of the Mississippi Valley and elsewhere.

Vermont.—In Vermont the problems presented for study in connection with the Cambrian rocks are somewhat of the same type as those

of New York. They differ in the northern portion, owing to the varying character of the sediment. Some of the questions are—

(1) The relation of the lower band of limestone ("Red sandrock"), bearing the Olenellus fauna, to subjacent rocks.

(2) The relation of the shore deposits, forming the "Granular Quartz" on the western slope of the Green Mountains, to the off-shore deposits, forming the limestones ("Red Sandrock") and shales (Georgia, etc.) carrying the Lower and Upper Cambrian faunas, in northern Vermont.

(3) The change in character of the sedimentation of the Cambrian rocks from the northern to the southern part of the State and their transition into the shale and slate series of New York.

(4) The determination of the extent of the range of the Cambrian fauna in the limestones of the "marble belt" in southern Vermont and the relations of these beds to the subjacent Cambrian strata on the western side of the "marble belt." The latter involves the question of the relation of the slates and shales carrying the Olenellus fauna and, in part, the base of what may be a portion of the Middle Cambrian fauna to the limestones. The working out of the complicated structural geology and the identification and mapping of all the formations will be required in the solution of these problems.

(5) The determination of the absence or presence of paleontologic data sufficient to differentiate the three primary divisions of the Cambrian group.

(6) The detailed geographic distribution of the formations referred to the Cambrian throughout the State.

Canadian extension.—The Cambrian group on the line of the Canadian extension north of Vermont, in the vicinity of Quebec and down the St. Lawrence River, requires detailed study in all its parts, both to determine the stratigraphic succession and character of the beds and the relation of the strata to the subjacent and superjacent series. One of the important problems presented is the determination of the origin of the limestone bowlders in the Point Levis conglomerate that carry the Upper Cambrian fauna, and those of the Sillery shale that carry the Lower Cambrian or Olenellus fauna. In fact, the entire Cambrian group of this portion of Canada requires full investigation.

New Jersey.—In New Jersey it is desirable to ascertain:

(1) The relation of the quartzite that has been referred to the Potsdam, to the subjacent Green Pond Mountain rocks.

(2) The representatives in New Jersey of the Pennsylvania Primal slates of Prof. Rogers.

Pennsylvania.—In the State of Pennsylvania attention should be given:

(1) To determining, by paleontological evidence, the exact age of the quartzite which has been referred to the Potsdam sandstone by all authors.

(2) To a careful study of the upper Primal slate, for the purpose of determining the line of demarcation between the Cambrian and Silu-

rian (Ordovician) rocks. This, apparently, will have to be based upon the paleontological evidence, as the stratigraphic series is unbroken and there is a gradual gradation between the schists or slates and the limestone by the intercalation of calcareous beds in the shales until the latter predominate and form the limestone series. This investigation can probably be best carried on in York and Adams Counties and the western portion of Lancaster County.

(3) The relation of the quartzite to the subjacent rocks also requires careful investigation all along the line of contact of the two terranes.

(4) Another problem that requires investigation is whether the Primal slates and schists graduate into limestones to the east and northeast of Lancaster County, or whether there is a line of unconformity, by non-deposition, between the quartzite and limestone in Chester, Berks, Bucks, Lehigh, and Northampton Counties. In other words, whether the portion of the Cambrian section as found in York and Adams Counties is absent in the counties to the northeast, or if it be represented by the lower portion of the limestone series.

Virginia.—The knowledge of the stratigraphic position of the rocks referred to the Cambrian, in Virginia, is in a much more satisfactory condition than that of Pennsylvania. It is desirable, however, that attention be given to:

(1) The changes in the character of the sedimentation from the Tennessee line north to the Potomac, and also the changes in the character of the sediment between the shore deposits of sand and conglomerate and the off-shore deposits of shale and calcareous matter.

(2) The paleontologic evidence of the geologic age of the strata referred to the Cambrian, is very defective, and investigation in this line should be made throughout the State.

North Carolina.—The problems to be considered in North Carolina are:

(1) The section along the French Broad, so as to determine the age of the strata and, if Cambrian, ascertain the stratigraphic position of the limestones, shales, sandstones, and quartzite to each other and to the sections of eastern Tennessee.

(2) About the same problem is presented in the rocks on the line of the Iliwassee section, in the southwestern portion of the State.

Tennessee.—The questions requiring investigation in Tennessee are:

(1) The stratigraphic relations of the Chilhowee formation to the Knox sandstone and Shale series.

(2) The relations of the eastern shore deposits to the off-shore deposits westward of the pre-Cambrian rocks.

(3) The collection and the study of the faunas of the Chilhowee and Knox shale formations.

(4) The geographic distribution of the strata and the vertical range of the faunas.

Georgia and Alabama.—The entire Cambrian section of Georgia and Alabama needs to be worked out stratigraphically, especially the rela-

tion of the Coosa Valley shales to the quartzites referred to the Chi howee formation of Tennessee. The fauna of the shales is large an varied, and should be studied in connection with that of the Cambria section of Tennessee and New York.

Utah and Nevada.—The problems awaiting solution in the study c the Cambrian rocks of Nevada and Utah are of an unusually interestin character. Those that suggest themselves are:

(1) The study of the basal beds of the Cambrian, and the possible ex tension of the Olenellus fauna down into the quartzite series beneat what is now recognized as the Olenellus zone. From all that is know to me of the rocks in Nevada and Utah, I think that in western centra Nevada the best opportunity will be found for the discovery of th faunas preceding the present recognized base of the Cambrian. Dur ing later Algonkian time there appears to have been a great accumu lation of arenaceous and siliceous sediments along the line of the Wa satch and extending westward into central Nevada. In western Nevad they are more shaly and calcareous, and it is possible that the cond tions under which they were deposited were more favorable for th presence and preservation of the life of that period.

(2) The careful and detailed study of the great Cambrian section c central Nevada for the purpose of determining the full sequence of lif throughout. Our present knowledge of it is very incomplete, and ther are many gaps that can probably be filled in by detailed work and th careful collection of the fauna in connection with the study of strat graphy and sedimentation.

(3) The study of the sections from the Wasatch westward to wester Nevada for the purpose of determining the change of sedimentation an life from east to west.

(4) Another important subject of investigation is the transition be tween the Upper Cambrian and Ordovician faunas. This has been par tially worked out in the Eureka district section, but there still remain much to be learned by careful detailed study of the sediments an faunas in the field.

(5) One of the unsolved problems of Utah is the question of the geo logical age of the quartzite beneath the Carboniferous limestone sur rounding the main quartzite series of the Uinta Mountains. It i probable that there is a series of Cambrian rocks beneath the limeston and above the quartzite as in the Big Cottonwood Cañon section of th Wasatch Range; but it will remain an open question until paleonto logic evidence is obtained.

Colorado.—Investigation in Colorado should be directed toward dis covering fossils in the strata referred to the Upper Cambrian zone, an to verifying the exact stratigraphic position of the beds carryin Dikelocephalus at Quandary Peak.

Rocky Mountains.—In the eastern district of the Rocky Mountai Province it is desirable that close study should be made of the variou

sections of the eastern ranges of Colorado, Wyoming, and Montana, for the purpose of detecting the presence and character of the fauna as a means of correlating the strata with those of the Black Hills and the upper Mississippi Valley. On the western side, in southeastern Idaho, the Gallatin River section needs special investigation in order to correlate it with the sections of Nevada. Reference to what is required in Utah, Nevada, and Colorado has already been made.

Arizona.—It is desirable that larger collections should be made from the lower sandstone of the Cambrian section in the Grand Cañon area, and that the geographic distribution of the Cambrian in western Arizona be determined.

Upper Mississippi Valley.—Through the work of the Wisconsin and Minnesota surveys our knowledge of the Upper Cambrian sandstone is unusually complete. It is desirable that more information should be obtained in relation to the distribution of the fauna in the section and to ascertain whether the Middle Cambrian fauna accompanied the invasion of the sea that deposited the lowest beds of the terrane.

To determine the age of the sandstones on the south shore of Lake Superior it is still necessary to obtain paleontologic evidence to enable the geologist to state positively that the sandstones are the geologic equivalent of the fossiliferous sandstone of the central area of Wisconsin. It is also desirable to trace the continuation of the recognized fossiliferous Upper Cambrian sandstone directly west of Green Bay, Wisconsin, with that occurring on the south shore of Lake Superior. The definite settlement of these two problems will remove what has long been the source of contention among geologists.

Missouri.—It is desirable that the exact line of demarcation between the Upper Cambrian and Silurian (Ordovician) zones should be determined and more positive paleontologic data be obtained of the relative stratigraphic position of the beds with those of other areas that are now referred to the Cambrian.

Texas.—The information in relation to the Cambrian area of central Texas, in Llano County, is sufficient for most geologic purposes, although more detailed information as to the horizontal distribution of the fauna and the presence or absence of the Middle Cambrian fauna is desirable. The principal question, however, is the investigation of the supposed Cambrian in the vicinity of El Paso and the southwestern portion of the State.

PROBLEMS AFFECTING OUR KNOWLEDGE OF THE CAMBRIAN GROUP AS A WHOLE OR IN LARGE PARTS.

A glance at the map delineating the distribution of the Cambrian strata as shown by outcrops in North America, Pl. I, reveals at once the fact that we are dealing almost entirely with a marginal or coast series of sediments that are largely covered, over great areas, by later

deposits. It is only here and there that a deep-seated disturbance has brought up the sediment that accumulated at some distance from the shore line. In Vermont and Nevada, especially in the latter, the calcareous sediments forming the limestone have been brought to the surface. In the great interior area of Wisconsin, Missouri, Texas, and the eastern front of the Rocky Mountains and the northern line between Canada and New York nothing is known of the deeper water deposits, if any such existed.

We know something of the sediments that accumulated along the western shore line of the Appalachian protaxis; but what was deposited over the area of which Ohio, Indiana, Kentucky, Tennessee, northwestern Alabama, Mississippi, northern Texas, Indian Territory, Kansas, and Nebraska forms a part we know nothing.

From the fact that in Texas, Missouri, the Upper Mississippi Valley, along the eastern front of the Rocky Mountains, and in New York and Canada west of the Adirondacks the deposits are such as would accumulate in a shallow sea not far distant from the shore line it has been assumed that the Cambrian ocean of this great area was relatively shallow. I think that during Lower and Middle Cambrian times the entire interior continental area was above the sea level. These opinions are based on the character of the deposits and the absence of the sediments of the Lower and Middle Cambrian. The great problem in this connection, however, is to determine how far the pre-Cambrian continent extended to the south and east and what its relations were to the offshore ridges of the eastern and western margins, along which we now find deposits of Lower and Middle Cambrian age.

A careful study of the sections in Pennsylvania, Virginia, Tennessee, Georgia, and Alabama may throw some light upon the question on the southeastern side. Over the remaining portions of the great central area no natural outcrops are known, and there seems to be no way of obtaining information except by very deep borings.

The question of the relations of the Middle Cambrian fauna of the Atlantic Coast Province to that of the Appalachian and Rocky Mountain Provinces is one that can be settled only by a close and careful study of the faunas, based on large collections methodically made throughout the entire areas of the three provinces. That the Middle Cambrian or Paradoxides fauna of the Atlantic Coast Province is represented by a very different fauna in the Rocky Mountain Province there is not, I think, any question. It is also well proved that the latter fauna is present to a less extent in the Appalachian Province.

Throughout the Rocky Mountain Province, except in British Columbia, the Olenellus or Lower Cambrian fauna is confined to a very narrow zone, while in Vermont it ranges through 1,000 feet of limestone and up into the superjacent shales. In New York it has a range through a great thickness of shales, slates, interbedded limestones, and sandstones; and one of the problems requiring investigation is the downward

extension of this fauna in the series of shales, slates, and sandstones beneath the now known Olenellus horizon of the western Rocky Mountain Province. The lower series of slates and quartzites have been tentatively referred to the Algonkian, but it is quite probable that they will be found to carry the Olenellus fauna to a considerable depth, and a pre-Olenellus fauna may yet be discovered.

The problem of the downward extension of the Cambrian faunas also requires investigation in the Appalachian Province, especially in the southern portion—in Tennessee, Georgia, and Alabama. The basal limit of the Cambrian is now drawn at the Olenellus zone, but in the absence of any subjacent fauna there still remain the problems of the downward extension of the Cambrian fauna and of the existence of a pre-Cambrian fauna that may have lived in the Appalachian seas.

A local question of interest may be here introduced, as it affects a considerable area and involves conditions of sedimentation unknown elsewhere in the Cambrian. It is the question of the place of derivation and mode of transportation of the bowlders of the limestone conglomerates that carry in the lower zone, the Lower Cambrian, and in the upper zone the Upper Cambrian fauna found along the southern shore of the St. Lawrence River from Quebec to Gaspé.

One of the problems partially solved, and one that still requires investigation, is the relation of the pre-Cambrian topography to the sediments deposited upon it, to determine the source of sediments and the habitat of the faunas.

Along the Atlantic coast the presence of the pre-Cambrian shore line with a varied coast topography is clearly distinguishable, and it is evident that the Cambrian strata now occupy the same relative position to the pre-Cambrian as the sediments did when they were deposited. The same is true of the shore-line deposits along the western margin of the Appalachian, pre-Cambrian protaxis, and the sediments about the Adirondack area. Between the Adirondacks and the Green Mountains a great thickness of Cambrian rocks appears to have been deposited in a deep, relatively narrow sea; but what the conditions were to the westward of the long line of the eastern boundary of the Appalachian Province is one of the questions requiring solution. The same is true of the western limits of the sediments now exposed in the great uplifts of central Nevada and British Columbia.

The questions arising from the study and comparison of the various provinces all require a more thorough investigation of the sections of the western Rocky Mountain, Appalachian and Atlantic Coast Provinces. They bear upon the nomenclature and classification to be adopted for the Cambrian group; and not until we have a more thorough knowledge of the sections of northern Vermont, New York, Tennesse, British Columbia, and Nevada can the classification be considered more than a provisional one.

PROBLEMS OF NOMENCLATURE AND CLASSIFICATION.

The name.—It is still a debatable question with a few geologists, whether we shall follow the present general usage and use the name Cambrian group, with the area of Cambrian in Wales as its type and the descriptions of Prof. Adam Sedgwick as the classical description of the group, or, in opposition to this, adopt the name Taconic, proposed by Dr. Ebenezer Emmons, with the area of Berkshire, Rensselaer, and Washington Counties, east of the Hudson River, in New York, as the type, and the papers of 1842 and 1844 of Dr. Emmons as the classical description of the group.

While recognizing the fact that the name Taconic has certain claims upon the sentiment of Americans, I have stated elsewhere that I think the interests of geology are best served by adopting the term Cambrian, as has been done by the great majority of geologists.

The limit of the group.—The delimitation of the upper limit of the group by geologists who recognize it as distinct from the superjacent Silurian (Ordovician) has varied to the extent of placing the arenaceous deposits of the shore line, or the strata referred to the Potsdam sandstone, in the Silurian, or including the superjacent Calciferous formation in the Cambrian. To a large extent this difference of opinion is based upon the evidence of the local physical conditions of sedimentation, and not upon the included faunas. If we adopt as the principle of classification that the delimitation of the great geological groups must rest upon the broad zoological characters of their included faunas and not on local stratigraphic breaks between certain series of rocks, or on local differences of sedimentation, the line of demarkation between the Cambrian and Silurian (Ordovician) is to be drawn where the marked characters of the Cambrian fauna give way to those of the Ordovician. That this principle is the only sound one upon which to base the delimitation of a group is proved by the fact that there is no other relatively constant character upon which to rely in geologic classification. That it is often arbitrary is known to all working geologists.

The line of demarcation along the northern and eastern sides of the Adirondacks is between the upper beds of the Potsdam sandstone and the calcareous layers of the Calciferous formation. On the south side, in Saratoga County, it is drawn in a series of limestones, where the characteristic Upper Cambrian fauna disappears and the types of the Silurian (Ordovician) fauna appear. In western Vermont, 20 miles from where the division is made between the Potsdam and Calciferous formations, the line is drawn in a series of black argillaceous shales, somewhere between a horizon carrying characteristic Upper Cambrian fossils and another horizon some distance above, in which characteristic Calciferous fossils are found. In the Southern Appalachian Province, in East Tennessee, the line of demarcation is not at the base of the limestone series, but at a point in the lower portion of it,

where the characteristic Upper Cambrian fauna disappears and the Silurian (Ordovician) fauna begins to predominate. This same principle of demarcation is followed in the limestone series of central Nevada, while over the interior continental area it is largely drawn at the summit of the sandstone carrying the Upper Cambrian fauna and at the base of the limestone in which the Calciferous fauna occurs. In some instances, however, the Upper Cambrian fauna extends up into the Calciferous beds, and in such the line of demarcation occurs in the Calciferous zone.

It is not always possible to delineate on the map such close lines of demarcation within a formation, and for the sake of convenience it may be well to map the formation by their lithologic characteristics and describe in the text the line of delimitation between the groups. When, however, the line between two groups occurs in a limestone, as in the Pogonip limestone of the Eureka district, Nevada, and there is sufficient paleontologic evidence to demonstrate it, the line should be drawn on the map at the point indicated by the faunas.

The problems in connection with the delimitation of the summit of the Cambrian group remain to be studied in nearly all portions of the various provinces. In some they are fairly well settled, but there still remains much to be done in the way of collecting the faunas and studying their vertical distribution in the strata.

Is the basal line of the Cambrian group at the lowest limit at which the Olenellus fauna is found? Where this lowest limit occurs at the base of a conformable series resting unconformably upon pre-Cambrian rocks there is no difficulty in answering the question. But where it occurs in the midst of a conformable series and there remain thousands of feet of sediments beneath the Olenellus zone, as in Nevada and Utah, it still remains a problem for consideration. On the general proposition that I would not refer to the Cambrian any rocks beneath the Olenellus zone, the subjacent strata of the western Rocky Mountain area were referred to the Algonkian in the paper reviewing the Lower Cambrian or Olenellus fauna published in the tenth annual report of the U. S. Geological Survey. I think, however, it is a question for discussion and research, as the Olenellus fauna has a great vertical and time range in the Northern Appalachian Province, while in the Southern Rocky Mountain Province it is limited to the very narrow band of strata at the summit of the siliceous series of slates and quartzites.

That the question of how the Cambrian shall be divided in America still requires investigation, with special relation to the classification to be applied in the various provinces, is well known. The three primary divisions of the Cambrian (Lower, Middle, and Upper) are readily recognized in Newfoundland, and that one or the other of these divisions can be distinctly recognized in the other provinces has been proved.

In the Interior Continental Province only the Upper Cambrian, with

its distinct sedimentation and fauna, is known, and no other appears to have been deposited. In the Appalachian Province, in Vermont, the Lower Cambrian is readily separated by organic remains and sedimentation; but with our present knowledge it is impossible clearly to distinguish between the Middle and Upper Cambrian. The same is true throughout the Appalachian region, except in the Adirondack subprovince, where the Upper Cambrian is well developed. In the Rocky Mountain Province the Lower Cambrian is distinctly developed, but the Middle and Upper merge more or less into each other. The problems in this connection requiring investigation are clearer delimitations of the Middle and Upper Cambrian in the Appalachian and Rocky Mountain Provinces, both by the careful study and comparison of the sections and the collecting and differentiation of the faunas.

It is not anticipated that uniformity will be found to exist in each of the primary subdivisions; the sedimentation of the various provinces is too unlike. The three divisions will have to be used, if at all, in a somewhat arbitrary manner in some of the areas, just as the greater division of the Cambrian is arbitrarily separated from the Silurian (Ordovician) where no physical line of division is apparent. We recognize the Cambrian group as a convenient means of classification, but its subdivisions must be controlled by the needs of the local geologist and not used unless distinctly recognized.

CHAPTER VI.

THE CRITERIA AND PRINCIPLES USED BY AUTHORS IN THE CORRELATION OF THE VARIOUS PARTS COMPOSING THE GROUP, WITH OBSERVATIONS ON SOME METHODS OF CORRELATION.

HISTORICAL NOTES.

The earlier American geologists took their first views of classification and principles of correlation mainly from European authors. Among the latter Dr. John Woodward said early in the eighteenth century in his "Natural History of the Earth":

> That the stone and other terrestrial matter in France, Flanders, Holland, Spain, Italy, Germany, Russia, and Sweden were distinguished in *strata* or *layers* as it is in England; that these strata were divided by parallel layers; that there were inclosed in the stone and all the other denser kinds of terrestrial matter great numbers of the shells and other productions of the sea in the same manner as in that of this island.[1]

This is one of the earliest correlations of stratified and fossiliferous rocks. It is crude and indefinite as compared with modern correlation, but the general method of comparing stratified fossiliferous rocks because they are stratified and fossiliferous was inaugurated.

Dr. Abraham Werner, in Germany, gave systematic form to descriptive geology in the latter part of the eighteenth century; while about the same time Prof. William Smith, in England, applied organic remains in geologic investigation, and correlated formations in various parts of the British islands by their contained fossils. A little later Baron George Cuvier was establishing in France the great principles of the succession of varying organic remains in the strata and their differentiation from living forms.

AMERICA.

Maclure.—In America Mr. William Maclure was among the first to take advantage of the principles of classification enunciated by Dr. Werner, and we find the correlations made by him in preparing his geological maps were based entirely upon lithologic and stratigraphic evidence. This is stated in the first paragraph of the introduction to his paper:[2]

> Necessity dictates the adoption of some system. So far as respects the classification and arrangement of names the Wernerian appears to be the most suitable, first, because it is the most perfect and extensive in its general outlines, and secondly,

[1] An Essay towards a Natural History of the Earth and Terrestrial Bodies. London, 3d ed., 1723.

[2] Observations on the Geology of the United States explanatory of a geological map. Am. Phil. Soc. Trans., vol. 6, 1809, pp. 411, 412.

the nature and relative situation of the minerals in the United States, while they are certainly the most extensive of any field yet examined, may perhaps be found to be the most correct elucidation of the general exactitude of that theory as respects the relative position of the different series of rocks.

On the map four great classes of rocks are recognized: Class I, Primitive rocks; II, Transition rocks; III, Secondary rocks; IV, Alluvial rocks. The presence of rock salt in the southern Appalachian is recognized by a separate color.

In the text[1] the Primitive rocks are divided into fourteen varieties, the Transition into five varieties, the Secondary into twelve, and the Alluvial into seven. In traversing the country Mr. Maclure noticed the presence of any one of these rocks at their various outcrops, and thus correlated the geological formations that presented similar characters. In the second edition of his work[2] two methods of examining and correlating the rocks are given:

The first, the accurate investigation of a small portion of the surface, describing exactly the different rocks with their immense variety of arrangement and position of their component parts, detailing the changes, accidental or natural, constantly occurring in their relative situation, and endeavoring to reduce the whole to some regular series of arrangement. This method necessitates the reunion of a great number of those portions before any correct general idea can be formed.

The second, beginning with the great outline, traces the limits which divide the principal classes of rocks and their relative situation and extent. Mr. Maclure favors the second, stating:

> In tracing the outlines of the different formations in most countries there is less confusion and embarrassing description necessary; the limits once ascertained, a few pages define the boundaries and explain the relative situations to the comprehension of every reader.[3]

Eaton.—After Mr. Maclure, Prof. Amos Eaton was the most important factor in the shaping of the methods of geologic work in America. By his various publications and his influence as a teacher he outlined the methods and formulated the general principles upon which geologic investigation was carried forward for nearly two decades. The correlations made in his earlier works were based entirely upon the lithologic characters of the rocks. Believing in the Mosaic cosmogony, he explained the phenomena he observed in the structural relations of the rocks by the giving way of the foundation of the Old World prior to the flood. He says:[4]

> While this tremendous crash of nature was going on, scales of various thicknesses from the various strata were shot up, detached, and broken, which gave formation to our surrounding hills, the ragged cliffs of the Catskill, and the bleak brow of the

[1] Op. cit., p. 412.

[2] Observations on the Geology of the United States; with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils. Am. Phil. Soc. Trans., vol. 1, new ser., 1817, pp. 1–91.

[3] Op. cit., p. 9.

[4] An index to the Geology of the Northern States, with a transverse section from Catskill Mountain to the Atlantic. Leicester, 1818, pp. 48, 49.

Andes. Some were formed at the bottom of the sea by volcanic fires, others have arisen from various causes since the great deep retired.

During the deluged state of the earth many species of animals were probably destroyed. For we continually find the petrified remains of species of animals now totally extinct.

From the latter observation it is quite evident that at that time he did not consider fossils to be of any value in the correlation of the rocks. In the next edition of the Index [1] his theories of the origin and first condition of the surface and position of the rocks are omitted, and a more thorough description is given of the various rock masses, the classification of which was lithologic and based on the views of Dr. Werner. His more extensive work of 1824[2] shows that the correlations made between the rocks of the Hudson and those west of the Hudson, along the line of the Erie Canal, were based mainly upon their lithologic characters. For instance, the Calciferous sandrock of the Mohawk Valley, in the vicinity of Little Falls, New York, was traced westward in the vicinity of Utica and eastward down the Mohawk Valley to the vicinity of Schenectady, and then correlated with a Calciferous sandrock on the east side of the Hudson. This correlation was made upon the lithologic character and the stratigraphic succession of the rock masses. Its defective character is shown by the fact that the Calciferous sandrock east of the Hudson is of Lower Cambrian age and that west of the Hudson is of Silurian (Ordovician) age.

Classification and correlation on the basis of lithologic character and stratigraphic succession was continued by Prof. Eaton in his work of 1828[3] and again in his text-book of 1830.[4] On the map accompanying the latter all the quartzose formations are colored yellow, all the calcareous formations blue, the variegated sandstones red, and the subordinate rocks green. By this the primitive limestones of the Adirondacks (Algonkian), the Lower Cambrian limestones of Washington County, the Calciferous-Chazy-Trenton limestones of the central portions of the State, and the Lower Devonian limestones of the Upper Helderberg are all placed under one color.

In 1832[5] he introduced a new heading into his Text Book, as follows: "Organized remains as auxiliaries in the determination of rock strata." Under this he says:

The remains of similar species of animals and plants are found embraced in similar series of rocks; and these occurrences are so uniform that rocky and earthy strata may be determined by them.[6]

[1] An Index to the Geology of the Northern States, 2d ed., 1820, pp. 286.

[2] A geological and agricultural survey of the district adjoining the Erie Canal, 1824, pp. 163.

[3] Geological nomenclature, exhibited in a synopsis of North American rocks and detritus. Am. Jour. Sci., vol. 14, 1828, oppo. p. 144, pp. 145–149, 359–368.

[4] Geological text-book, prepared for popular lectures on North American geology; with applications to agriculture and the arts. Albany, 1830, pp. 64.

[5] Geological text-book for aiding the study of North American Geology; being a systematic arrangement of facts, collected by the author and his pupils, under the patronage of the Hon. Stephen Van Rensselaer. 2d ed. Albany, 1832.

[6] Op. cit., p. 25.

In connection with the discussion of the presence of organic remains in the rocks the following passage occurs:

The geological deposits of this country (and probably those of the eastern continent) exhibit grounds for conjecture if not absolute demonstration that the surface of the earth has undergone five general modifications, which no animals survived. Four of these modifications were followed by as many new creations of animals. Also that two new creations of animals succeeded the final depositions of all regular strata. In the whole, there appears to have been five creations of animals at least (perhaps ten) since the primitive m ass of the earth was formed, and a long interval succeeded each creation.[1]

It is also said that the "remains or impressions of plants are limited to coal and coal formations whose relative position is indicated by their rocky associates; the determination of rocks by their animal relics serves as an index to the position of coal measures or beds. In this concise selection of the most essential relics animals alone will be noted which have no backbone nor brains" [invertebrates].[2]

Under the title of "Geological Equivalents" Prof. Eaton mentions that relative position and mineral constituents were deemed sufficient by Werner for determining geological equivalents. As relative position is the basis of the science, all other circumstances have always been received as auxiliaries only so far as classification is concerned.[3] He reasoned that as rocks can be traced more or less continuously throughout New York and Pennsylvania the data used by Werner are of value; but—

From a consideration of the cases here referred to, intrinsic characters more definite than any left us by Werner seem to be essential to the progress of the science. The enumeration of mineral consti tuents of rocks can never be satisfactorily applied. Unorganized matter presents but few characteristics. Naturalists find it a more difficult task to describe by external characters about two hundred and seventy species of minerals than fifty thousand species of plants and a still larger number of animals.

It is a subject of high congratulation to students in geology of our day that the illustrious Cuvier, aided by the Brongniarts and their coadjutors, have extended the science of organic nature to the science of geology. We are no longer limited to the enumeration of mineral constituents. We find the same organized remains associated with equivalent strata in every part of the earth, though they often extend into several adjoining strata, which are probably contemporaneous or nearly so.[4]

He then proceeds to classify the strata as known to geologists of both continents by means of some of their organic associations in North America.[5]

A few months later he published a paper on "Four cardinal points in stratigraphical geology established by organic remains," saying:

If the identity of the *Granular*, the *Metalliferous*, and the *Oolitic calcareous rocks*, and of the *Tertiary marls* are established on both continents all intervening strata may be ascertained with great facility. I think that a reference to the following facts will be sufficient to establish their equivalent characters at least.[6]

---

[1] Op. cit., p. 48.

[2] Op. cit., p. 25.

[3] Geological equivalents. Am. Jour. Sci., vol. 21, 1832, pp. 132-138.

[4] Op. cit., p. 134.

[5] Op. cit., pp. 136–138.

[6] Four cardinal points in stratigraphical geology established by organic remains. Am. Jour. Sci., vol. 21, 1832, p. 199.

The first cardinal point is the Granular limerock "the only limerock which is always destitute of organic remains." The second cardinal point is the Metalliferous, Mountain or Carboniferous limerock. Under this heading he correlates the limestone at Trenton Falls and most of the limestones of New York. The third cardinal point embraces the Oolitic series or Calcareous rocks, and the fourth the Tertiary marls. These correlations of Eaton were crude, but when refined by the geologists of the New York State survey the first three formed the basis for the correlation of the lower and middle Paleozoic rocks of the continent.

Bigsby.—The earlier work of Dr. J. J. Bigsby was apparently unknown to Eaton. The former used organic remains in a very general manner to correlate the strata of England and America, but also depended upon the lithologic characters and stratigraphic succession. In an article entitled "A list of minerals and organic remains occurring in the Canadas" he remarks upon the extent and relations of the limestones and sandstones of the eastern and western parts of Canada. Of the limestones he says:

Their relation to the subjacent rocks and uniform similarity in structure and contents, mineral as well as organic, seem to indicate that the beds of limestone, extending with few or no interruptions from Cape Tourment, below Quebec, to near the Falls of St. Mary, are the effects of a contemporaneous deposition; and further, that they are the representatives of the Mountain or Carboniferous limestone of England.

I make these statements with extreme diffidence, being in some degree aware of the difficulties of the discussion, of the existence of contradictory facts, few but weighty, and of the defective state of our information respecting the vast calcareous formations of North America.[1]

The reference to the secondary limestone of the St. Lawrence and the lake region is as follows:

The limestone now described abuts on one of the older rocks directly, or with the interposition of another horizontal stratum, and by far the most commonly on gneiss, which I have strong grounds for believing to be of the same age and general characters throughout the whole of the districts under consideration. It is incumbent directly on gneiss in the bed of the river St. Anne, near its upper falls, in the seigniory of St. Feriole, Lower Canada; at Montmorenci, not far from "the natural steps," but only seen in time of low water; at and near Point Henry, close to Kingston, Upper Canada; and in many places on the north coast of Lake Huron. In the last-named locality it rests directly, in several instances, on a beautiful snow-white transition quartz, which occupies the main shore in steep hills, 400 and 500 feet high, from near the French River to the River Le Serpent (70–80 miles). The immediately subjacent rock at La Cloche and on the isles north of the Manitoulines, in the same lake, is sometimes a highly inclined greenstone. Near Montreal it overlies directly crystalline trap, containing augite, zeolite, mica, feldspar, etc.

But ordinarily a sandstone, graywacke, or a conglomerate of quartzose or calcareous materials is interposed; also in horizontal layers. It is to be remarked (en passant) that much the greater part of the graywacke of Lower Canada does not belong to this deposition, but is conformable to the mica-slate, gneiss, etc., ranging along the north shore of the St. Lawrence, between Quebec and the river Saguenay. * * *

[1] A list of mineral and organic remains occurring in the Canadas. Am. Jour. Sci., vol. 8, 1824, pp. 76, 77.

The sandstone, which is beneath the limestone from near Kingston, Upper Canada, to St. Anne's, 26 miles northwest of Montreal (174 miles), is white, but with ferruginous spots and clouds, hard, fine grained, without cement, and contains thick layers of large and small nodules of crystalline quartz, disposed in horizonal lines. It forms cliffs an hundred feet high in the Lake of the Thousand Islands, which rest on the very small-grained gneiss (often a granite) which abounds so in the north and northeast and passes largely and frequently into primitive white quartz rock, thus disclosing a possible source of the sandstone and quartz nodules. Where clay is the cement an argillaceous sandstone or graywacke is furnished. The former of these I have never seen in contact with the inclined rocks. It occurs very distinctly in the chasm of the Niagara, the lower strata of which (and particularly those on which Queenston stands) are almost ferruginous clay. The nearest primitive is on the north shore of Lake Simcoe, 90 miles off. From the nature of the organic remains and other contents of the limestones covering this sandstone, I am inclined to believe the latter to be the old red, which is often thus intermixed with argillaceous matters. At Dunkirk, on the south side of Lake Erie, Mr. Hulbert has bored through these rocks to the depth of 682 feet (117 feet below the surface of the Atlantic) and without meeting with salt. The above observations apply to the fine sections in the bed of the Genesee River; but I have not sufficiently examined the fossils in the limestone of that locality. Its sandstone has large but indistinct casts of what I suppose to be encrinites, but which may be vegetable, but in either case resembling the Old Red sandstone. It may be added that it is on the same level with and not very far from the sandstone of the vicinity of Kingston; but similarity in level taken by itself is not an unerring test of similarity in age. In one part of a district or lake granite, gneiss, etc., may attain a given elevation and be there covered with graywacke only; while in another and not very distant place these rocks may not rise to within some thousand feet of that height, and be buried under all the succeeding strata up to the Crag above the London clay.[1]

A conglomerate wholly calcareous occurs in situ near the foot of the Long Sault of the river Ottawa, and at the Coteau du lac, 3 miles below Lake St. Francis, composed of angular and rolled masses, sometimes very large, of fine granular limestone light brown and blue, imbedded in a dark brown paste. A similar rock occurs with the limestone about Poughkeepsie, in the State of New York, and at Aubigny, opposite Quebec, interleaved with clay slate and graywacke, highly inclined, and having a southwest direction.[2]

The elements of correlation suggested in the preceding quotations include lithologic resemblance, similarity of level in a given area, stratigraphic succession, and the presence of organic remains.

At a later date Dr. Bigsby noticed in the conglomerates on the south side of the St. Lawrence, opposite Quebec, the presence of trilobites, encrinites, corrallites, and other fossils, and, on this account, considers the formation the equivalent of the Carboniferous limestone of the English geologists.[3]

James.—One of the earliest extended correlations in America is that of Dr. Edwin James.[4] In his remarks on the sandstone of the western part of the valley of the Mississippi he first describes in detail the red sandstone.[5] He states that this rock is the lowest of the horizontal or

[1] Op. cit., pp. 78–80.

[2] Op. cit., p. 81.

[3] On the geology of Quebec and vicinity. Proc. Geol. Soc. London, vol. 1, 1827, p. 38.

[4] Remarks on the sandstone and Floetz trap formations of the western part of the valley of the Mississippi. Am. Phil. Soc. Trans., vol. 2, new ser., 1821, pp. 191–215.

[5] Op. cit., p. 204.

secondary rocks met with and is very abundant in all that part of the plain immediately adjacent to the Rocky Mountains which he had examined. A similar rock is met with in the eastern part of the State of New York. Specimens from many parts of the strata on the Canadian River are entirely similar to those quarried in New Jersey and used in great quantities in the cities of New York, Albany, etc., for building.

"Whether this sandstone is in all respects similar to the 'Old Red sandstone' of Werner, which makes so conspicuous a figure in the systems of certain geologists, we are not able to say. It, however, certainly occupies a place similar to the one which has been assigned to that rock." In a foot-note referring to this statement it is said that—

This red sandstone is first found on the waters of the lakes on the strait between Lake Huron and Lake Superior, and forms the fall called the Sault de Ste. Maria.[2]

It also occurs in the Catskill Mountains and in the Salt District in the western part of the State of New York, having a similar relation to the secondary rocks in that quarter. * * * The red sandrock now under consideration appears at one place with every character requisite to place it among the rocks of transition, at another it is manifestly secondary; yet its continuity may be traced through minute shades of gradation or by a sudden transition from one of these points to the other.[3]

A review of the preceding remarks indicates that Dr. James supposed the Jura-Trias sandstone of the eastern foothills of the Rocky Mountains, the red sandstone of the Lake Superior region (Algonkian), the eastern New York sandstone (Upper Cambrian), and the New Jersey Triassic sandstone were of the same relative geologic age as shown by their lithologic characters and supposed stratigraphic position.

Bakewell.—The publication of the American edition of Mr. Robert Bakewell's Geology in 1829 was an important contribution to American geologic literature. It presents an account of the geological distribution of organic remains as then understood and the general principles of geology as known to English geologists.

In regard to correlation by fossils Mr. Bakewell says:

With respect to fossil conchology he is inclined to believe that the attempt to identify the strata of distant countries by the isolated occurrence of any particular species of shell has been carried further than a sound induction from facts or analogy would warrant. His opinion on this subject, given in the second edition of this work, he will here insert: "It may be doubted whether the occurrence of similar organic remains is sufficient to identify strata in distant parts of the globe; for could we admit that strata are universal formations and extended from the frozen to the torrid zone, it seems more than probable that the animals that lived on any one particular stratum would be of very different species in different latitudes." * * *

In strata belonging to one formation and in adjacent districts, the existence of certain shells, whether we regard them as distinct species or as varieties, may be of use in identifying any particular bed; and in distant countries where we find the same remarkable species of shell associated with any other remarkable species in considerable numbers it may serve to identify a particular rock formation, where the mineral character of the rock may be very different from that in which the observer has

[1] Op. cit., p. 205. [2] Op. cit., p. 206.

been accustomed to meet with them. The occurrence of a considerable number o gryphæ, the *Gryphea arcuata* in a bed of blue clay in the mountains around th Lake of Annecy in Savoy, served the author as a key to discover to what formatio the calcareous strata belonged, when their mineral characters would have indicate a more ancient series.[1]

De la Beche.—In 1832 an edition of the Geological Manual[2] of De l Beche was published in Philadelphia. In the section upon the classifi cation of rocks we find the following remarks upon classifiation b organic remains:

To propose in the present state of geological science any classification of rock which should pretend to more than temporary utility would be to assume a mor intimate acquaintance with the earth's crust than we possess. Our knowledge o this structure is far from extensive, and principally confined to certain portions o Europe. Still, however, a mass of information has gradually been collected, partic ularly as respects this quarter of the world, tending to certain general and importan conclusions, among which the principal are, that rocks may be divided into tw great classes, the stratified and the unstratified; that of the former some contai organic remains and others do not; and that the nonfossiliferous stratified rocks as a mass, occupy an inferior place to the fossiliferous[3] strata, also taken as a mass The next important conclusion is, that among the stratified fossiliferous rocks ther is a certain order of superposition, apparently marked by peculiar general accu mulations of organic remains, though the mineralogical character varies materially It has even been supposed that in the divisions termed formations there are foun certain species of shells, etc., characteristic of each. Of this supposition extende observation can alone prove the truth; but it must not be supposed, as some no do, that in any accumulation of ten or twenty beds, characterized by the presenc of distinct fossils in a given district, the organic remains will be found equally char acteristic of the same part of the series at remote distances.

To suppose that all the formations into which it has been thought advisable t divide European rocks can be detected by the same organic remains in various dis tant points of the globe is to assume that the vegetables and animals distributed over the surface of the world were always the same at the same time, and that they were all destroyed at the same moment, to be replaced by a new creation, differing specifically, if not generically, from that which immediately preceded it. From thi theory it would also be inferred that the whole surface of the world possessed an uni form temperature at the same given epoch.

It has been considered, but has not yet been sufficiently proved, that the lowes rocks in which organic remains are found entombed show a general uniformity i their organic contents at points on the surface considerably distant from each other and that this general uniformity gradually disappeared, until animal and vegetabl life became as different in different latitudes, and even under various meridians, a it now is. How far this opinion may or may not be correct can only be seen whe geological facts shall have been sufficiently multiplied; but it is one which demand considerable attention, as the classification of fossiliferous rocks greatly depends upo it. Should it eventually be found to a certain degree correct it would not be at va riance with the theory of a central heat, which having diminished permitted sola heat and light gradually to acquire an influence on the earth's surface.[4]

Numerous other European works soon came into the hands of the American geologists, among them the earlier editions of Bakewell,

[1] Introduction to Geology, Robt. Bakewell, 1st American edition, New Haven, 1829, pp. 32, 33.
[2] Geological Manual, Philadelphia, 1832.
[3] The term *fossiliferous* is here confined to organic remains.
[4] Op. cit., pp. 33, 34.

Lyell, Mantell, and various French and German authors. Their influence is shown by the rapid development of stratigraphic geology based upon the principles established in Europe. Of the means of correlation available to Prof. Amos Eaton in his earlier work he says, in 1839:

Eaton.—When I commenced my geological surveys the application of organized remains for demonstrating strata was not studied in America. I had become acquainted with no method for determining the character of such strata but that of tracing them separately through a vast extent of country and then comparing their general characters. For this purpose I traveled some thousand miles at my own expense and with the liberal aid of students of Williams College, with Prof. Dewey at their head, where I was employed more than a score of years since by the authorities of the college to introduce the natural sciences. Afterwards I traveled more than 17,000 miles on geologizing tours at the expense of the Hon. Stephen Van Rensslaer, and I was always aided by several assistants and competent students. Had the application of paleontology been then as well understood as it now is I could have settled the characters of most rocks as well in my closet by the aid of specimens. But it is a true remark in your last journal that strata must have been first settled according to the method to which I was compelled by ignorance to submit, before the service of organized remains could be successfully employed. In this country no material progress had then been made in the study of organized relics, and even now we have very few good paleontologists.[1]

NEW YORK SURVEY.

The geologists of the New York State survey systematized the work of the geologists who preceded them and established a standard section of the lower and middle Paleozoic formations of New York. On this account it is desirable to examine the principles of correlation mentioned by Messrs. Conrad, Hall, and Emmons and to notice the extension of the nomenclature of the formations of the New York section to various portions of the continent.

Conrad.—As paleontologist of the survey Mr. T. A. Conrad made the following comments upon the use of fossils in the correlation of strata:[2]

There is a strange misunderstanding of the method of applying organic remains in the division of series of strata into formations and the identification of widely separated rocks by the zoological characters of each. In the January number of the New York Review the opinion is advanced that the "Calymene blumenbachii ought to be carefully sought for in the rocks which are said to correspond to the Dudley period. Unless it is found, or some other consideration is introduced, can it be believed that fossils are a satisfactory evidence of the age and place of rocks?" The line of demarcation between rocks of different age has never yet been drawn with any accuracy by the aid of paleontology, except by the consideration of groups of species, one or even a few species having no weight whatever in the determination. Thus the shell termed *Terebratula Schlotheimii* dates its existence with the Trenton limestone, and reappears in three of the latter formations of the Silurian system. *Orthis testudinaria*, Dalm., is peculiarly characteristic of the Trenton limestone, by its almost invariable presence and extreme abundance, and yet it is also found in the limestone of the Helderberg, a formation of a far more recent origin. But, although a few species may have been continued through a succession of geological eras, the

[1] Cherty limerock or Corniferous limerock, proposed as the line of reference for State geologists of New York and Pennsylvania. Am. Jour. Sci., vol. 36, 1839, p. 67.

[2] Second annual report of the paleontological department of the survey. Third annual report of the geological survey of New York, 1839, p. 58. Albany.

groups are widely distinct, and their value in determining the comparative age and identity of formations can never again be called in question by a geologist who deserves the name.

Attention is called to the fact that no observer has yet drawn the line of distinction between the Trenton and the newer limestone superimposed upon it in Ohio and Kentucky, because the similarity in mineral character and color is so perfect, and both formations thin out into mere seams and layers. It is also stated that the catalogues of organic remains of the Silurian system hitherto published in Europe are calculated only to mislead and confound the geological inquirer, as they are far too vague.[1]

In 1840 Mr. Conrad instituted a series of comparisons of formations of the New York section with those of England, based upon the fossils contained in their respectative formations. He compares the Caradoc sandstone with the limestone of Trenton Falls, and the Wenlock shale with the Rochester shale, and the Wenlock limestone with a limestone developed in the Helderberg Mountains.[2]

In the fifth annual report on the paleontology of New York we find the following remarks applied to correlation of the rocks of the State:[3]

The horizontally and undisturbed condition of the strata have enabled us to trace their sequence or order of superposition with comparative ease and greater accuracy than can always be obtained in regions where the formations have been much inclined or distorted. These divisions or series are usually composed of various layers, as compact limestone associated with friable shale, sandstone alternating with argillaceous shale, etc., and these modifications of their mineral constituents are generally accompanied by some variation of the organic contents; new species have been introduced, or more ancient ones have disappeared. But it is only at the junction of two formations that each *group* of organic remains is not perfectly distinct and characteristic, a mixture of species sometimes occurring which proves a gradual transition from one era to another, and gives rise to some uncertainty where the exact line of demarcation should be drawn. This fact opposes the idea sometimes indulged by speculative geologists, that sudden convulsions of the earth's surface have been the cause of exterminating forms of life, and the introduction of others to supply their place. The change seems rather due to alteration of temperature in the water, whatever new physical conditions of the earth resulted at the same time. Such phenomena, however, do not interfere with the general distinctive characters of the stratigraphical divisions adopted in this work. It is now, I believe, an undisputed point in geology that certain groups of organic remains belong exclusively to certain formations, and that these strata, in a general way, may be known and compared by the same groups of genera, if not species, in every region of the earth. It is also established, that whilst some genera and many species are restricted to a single formation, others have originated at an early period and continued to exist throughout a large portion of the time occupied in the deposition of a system or series of formations. * * *

The color and even mineral character of a formation usually varies greatly over an extended region, but it may be recognized by its fossil contents; for example, the black slate of the Mohawk, characterized by a peculiar trilobite, Triarthrus, which

[1] Op. cit., p. 59.

[2] On the Silurian System, with a table of the strata and characteristic fossils. Am. Jour. Sci., vol. 38 1840 pp. 87–91.

[3] Fifth annual report on the paleontology of New York. Fifth Annual Report of the Geological Survey of New York, 1841, pp. 25–27. Albany.

has never been known to occur in any other geological position, is represented by a drab-colored shale in the vicinity of Cincinnati, Ohio. There also the equivalent or continuation of the black limestone of Trenton Falls is of a gray or pale hue, and could be known as the same rock only by its organic reliquiæ. The Caradoc sandstone series of Wales is represented in New York by limestone and slate in proportion equal to the arenaceous strata.

Hall.—The desirability of naming formations from typical exposures to serve as standards of comparison for the purpose of correlation was enunciated by Prof. James Hall very clearly in 1839, as follows:

Everyone who has studied rocks even partially is aware of the insufficiency of mineral or lithological characters for giving nomenclature, and the many errors into which he may be led, whether in his own researches or by the mistakes of others. So likewise in the present state of our knowledge we are unable in all cases to give names from fossil characters; for, though without doubt every group embraces its peculiar fossils, yet in all localities these may not be so marked as to excite attention, and in some may possibly be absent. It thus becomes a desideratum to distinguish rocks by names which can not be traduced, and which, when the attendant circumstances are fully understood, will never prove fallacious. The basis of this nomenclature is derived from localities, and the rock or group will receive its name from the place where it is best developed.[1]

He then proceeds to name the "Rochester shale" from Rochester, New York, and the Lockport limestone from Lockport, New York.

In 1843, after stating the general results of an examination of a section southwest from Cleveland to the Mississippi River, he wrote:[2]

From the facts here stated the conclusion seems unavoidable, that the character of fossils is, or may be, as variable as lithological characters; in fact, that the species depend in some degree upon the nature of the material among which they lived. Fossil characters therefore become of parallel importance to the lithological; and, in order to arrive at just conclusions, both must be studied in connection, and localities of proximity examined. In the case of the Hudson River group of shales and sandstones, in passing from New York to Ohio, the lithological character is almost entirely changed; and at the same time also the most prominent and abundant fossils are unlike those of the group in New York. More careful examination, however, reveals the fossils which characterize this group at the East, and also at the same time some obscurely similar lithological characters. Similar lithological changes, accompanied by like changes in fossils, occur in more limited districts within the State of New York.

The most marked and important changes, however, appear to be in the higher rocks of the New York system. The Hamilton group and Marcellus shale, which in New York have a thickness of 1,000 feet, have diminished to 100 where last examined; and from being the group most prolific in fossils, as it is in New York, it has become entirely barren of them. The rocks forming the Portage and Chemung groups, which in their greatest development in New York are scarcely less than 3,000 feet in thickness, and in Pennsylvania much more, have in Indiana diminished to as many hundred. The upper of these groups, from being extremely fossiliferous, has become almost destitute of these characters, so that, at the farthest extreme examined, they furnish but an equivocal guide. In these groups lithological character is more persistent than fossils, and it requires a knowledge of the superposition to identify them satisfactorily. The greater thickness of these sedimentary deposits, and the greater

[1] Third Annual Report of the 4th Geological district of New York. Third Annual Report of the Geological Survey of New York. Albany, 1839, pp. 288, 289.

[2] Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a southwest direction; with remarks upon the identity of the western formations with those of New York. Assoc. Am. Geol. Trans., 1843, pp. 289-291.

development of fossils occurring at the same point, proves the organic forms to have flourished in a littoral position; and beyond these points, where the thinning of the strata indicates a greater distance from the shore the fossils diminish, and at the more distant and deeper points are not found at all. There is no evidence of denudation in these instances, and if there had been the parts left would have retained the same fossils, had it ever contained them, as they do farther east.

Throughout that part of the ancient ocean now occupied by Ohio, Indiana, Michigan, Illinois, and even to the west of the Mississippi, there appears to have been comparatively a small number of living forms existing from the period of the final deposition of the Helderberg limestones to the commencement of the Carboniferous period; while in New York, during the same period, there were a greater number of forms and individuals than in all the preceding periods. Without desiring to diminish the value of fossil characters as means of identifying strata, it must still be acknowledged that similar conditions in the bed of the ocean, and apparently similar depth of water, are required to give existence or continuation to a uniform fauna; and when we pass beyond the points where these conditions existed in the ancient ocean, we lose in the same degree the evidences of identity founded upon fossils. Some species, it is true, have lived onward through successive depositions, often of very different nature; yet, at the same time, these may not have had a very wide geographical range. In the case before us, some species have lived during the deposition of all the rocks from the Hamilton through the Chemung groups, and yet they have never extended themselves as far westward as Ohio and Indiana, although the nature of the deposits there was as favorable to their existence as in New York.

For the distance of 100 or 200 miles from the shores of the present continents the forms may be similar—we know not but they are—still who can say what changes may occur, or whether any exist in the depths 1,000 miles from land? From the nature of sedimentary deposits it can be only the finer parts that ever reach to great distances from their origin; and, reasoning thus, the fauna of the deep and distant parts of the ocean, if any exist, would be uniform, not being liable to destruction or change of condition from the rapid invasion of variable deposits like those near the shore. The deposition of a coarse sandstone or conglomerate succeeding to a shaly mass would in all probability destroy the greater number of living forms as far as it extended. But at the same time, the finer materials produced by the same cause would extend far beyond the limits of the coarser, and thus approximating in some degree to the lower mass, the fossils might be continued long after they were destroyed at another point.

One of the most interesting changes in the products on going westward is the great increase of carbonate of lime and the diminution of shaly and sandy matter, indicating a deeper ocean or greater distance from land. The source of the calcareous deposits is thus shown to have been in that direction, or in the southwest, while the sands and clays had their origin in the east, southeast, and northeast, producing a turbid condition in the waters of these parts during long intervals, which was unfavorable to the production of calcareous matter and the formation of chemical deposits. In New York we are evidently upon the margin of this primeval ocean, as indicated in the character of the deposits as well as organic remains; the southwest unfolds to us that portion where greater depth and more quiet condition prevailed.

At a later date he said:

I have met with no essay upon the geographical distribution of fossils in the older rocks; and the few facts here and there gleaned serve rather to stimulate than to satisfy curiosity. It has been a favorite opinion of many, and frequently advanced, that the condition of this ancient ocean was uniform and its depth *moderate*, and that the uniformity of organic products affords proof of the same. Without pretending to refute any theories or to establish general conclusions for the whole continent or for the whole globe, I shall merely offer a few facts which have fallen under my own observation, and this with the hope of calling the attention of other observers to the

subject and aid in deciding the true cause and amount of variation in paleozoic characters when examined over wide districts. We shall doubtless be led eventually to see in all these changes the influences of *depths of water, distance from or proximity to land*, and *the influence of the nature of that deposit* which formed the bed of the ocean, on which the animals lived. Every one of these causes, and perhaps other minor ones, have influenced the present character and condition of our older fossiliferous deposits. All these circumstances influence the organic productions of our present ocean, whatever may be the climate; and we have every proof that the same causes operated in this ancient sea, where, although depth and temperature may have been more uniform, yet these could not have been paramount to all other influences.[1]

He then proceeds to correlate the strata of the Mississippi Basin with those of the New York section by means of the contained fossils, and where possible the order of stratigraphic succession.

Emmons.—In a geological report of the midland counties of North Carolina, Dr. E. Emmons, in 1856, speaks of the classification of the sediments and says in this connection:

Superposition is, however, the highest proof of age, the oldest occupying the inferior position.

The bearing which fossils have to any scheme of classification which has been proposed can be understood only by a knowledge of the following laws: (1) *That species or kinds have had a limited duration;* (2) *that there has been a succession of species;* and (3) *that the species of one period, and which have become extinct, have never lived in any future period.* The utility of the knowledge of fossils is based on these three laws. This knowledge is particularly useful in comparing rocks which are widely separated from each other, or in those cases where direct superposition can not be observed. If, for example, certain rocks in Canada furnish a group of fossils similar to those of a given series in Tennessee, the inference would be that they belonged to the same period and hence occupy the same geological position; or, if we compare the fossils of the coal formation of England and America it will be found that they are almost identical; and it is proved also that the position relatively is the same in both countries, though separated from each other 3,000 miles.[2]

The extension of the New York section to the south along the line of the Appalachian Mountains was principally the work of the Rogers Brothers and Prof. Safford.

Rogers.—As geologists Messrs. H. D. and W. B. Rogers traced the the formations by stratigraphic continuity, lithologic characters, serial relation, and the presence of similar fossils as in the Trenton limestone, etc. I have not met with a statement of their views of geologic correlation except in incidental remarks. In a reply made to Prof. James Hall, who had congratulated the Profs. Rogers that they had borne such able evidence to the value of organic remains in determining the age of rock, Prof. W. B. Rogers said:[3]

That they had not been understood on this point; they had followed out the intricate structural geology of Pennsylvania and Virginia, relying chiefly on lithological characters, and had found to their great gratification that they had been working in parallel planes to the New York geologists, whose labors among the regular and

[1] Nature of the strata and geographical distribution of the organic remains in the older formations of the United States. Boston Jour. Nat. Hist., vol. 5, 1845, pp. 2, 3.

[2] Geological report of the midland counties of North Carolina. New York and Raleigh, 1856, p. 24.

[3] A system of classification and nomenclature of the paleozoic rocks of the United States, with an account of their distribution, more particularly in the Appalachian Mountain Chain. Am. Jour. Sci., vol. 47, 1844, p. 112.

horizontal strata of that State, relying on the evidence of fossil remains, had brought out results in the main quite consistent with the determinations of the Virginia and Pennsylvania strata.

In an address before the Association of American Geologists and Naturalists, Prof. Henry D. Rogers, in speaking of the tracks in the sandstone of the Connecticut Valley, says:

> Of the organic remains, through an investigation of which alone we can hope to establish the position of these strata in the scale of time, or reach definite conclusions respecting the physical conditions under which they were produced, the most instructive are the remarkable bird tracks, brought to light by Prof. Hitchcock, in Connecticut and Massachusetts.
>
> Guided by mere lithological resemblance, Maclure imagined this stratum to be the equivalent of the Old Red Sandstone of England.[1]

These passages imply that Prof. Henry D. Rogers considered paleontological evidence of the highest value in correlation, although in his work in Virginia he relied largely upon stratigraphic relations and lithology for the correlation of the Virginia with the Pennsylvania formations.

The correlation of the sandstone beneath the Trenton and Magnesian limestones of Pennsylvania, by Prof. H. D. Rogers and those that succeeded him, was based upon the stratigraphic position of the sandstone and the presence of *Scolithus linearis*, a fossil believed to be common to the Potsdam sandstone of New York and the lower sandstone of Pennsylvania.

The evidence of the identity of the sandstone with that of the Potsdam sandstone of New York, on the stratigraphic succession and position, is as follows:

(1) The formation is beneath a series of limestones, a portion of which is identified with the Trenton limestone by the contained fossils.

(2) The sandstone rests unconformably upon the crystalline gneisses forming the basal rocks of the Paleozoic period of Pennsylvania.

(3) The lithologic characters of the sandstone formation corresponded to that of the Potsdam sandstone of New York.

The paleontologic evidence is the presence of the annelid borings called *Scolithus linearis* in the sandstone of New York and Pennsylvania.

When once established this correlation was adopted and used by the first survey of Pennsylvania and also the second, but not altogether without protest by some of the workers in the latter. Mr. d'Invilliers[2] calls attention to this correlation of the Potsdam in the following words:

> It would be safer to name this formation the *Reading sandstone*, but in the descriptions of its outcrops along the Little Lehigh, the Lehigh, and the Delaware Rivers, in Vol. I of this report, it has been called *Potsdam sandstone*, taking for granted that any sand formation underneath the Magnesian limestones of the Great Valley must be the same sand formation which in northern New York underlies the Corniferous [Calciferous?], Chazy, and other limestones of the Mohawk Valley.

[1] On American geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, p. 248.

[2] The geology of the South Mountain Belt of Berks County. Second Geol. Surv. of Penn., D3, vol. 2, 1883, p. 99.

On the map of Adams County, based upon the results of geological work of Dr. Persifor Frazer, the quartzite resting upon Azoic is identified as Potsdam, with a question mark.

Safford.—In his first report upon the geology of Tennessee, Prof. J. M. Safford describes the method of the grouping of the strata into formations. He says:[1]

We often meet with a series of adjacent strata similar in many respects, so much so that they can conveniently be thrown together in a single *group* or *formation*, as such a series is often termed.

He says further:

For example, the *sandstone*, *slates*, and *coal* which form the upper part of the Cumberland Table-land, are grouped in a *formation*, called the *Coal Measures*, with the following among other common characters: *First*, coal is found at intervals throughout the series; *secondly*, there is very little limestone or calcareous matter in the series; *thirdly*, the strata are parallel, and appear to have been formed in succession, under similar circumstances; *fourthly*, the same *fossils*, such as different species of petrified shells, leaves, branches, and trunks of trees, etc., occur imbedded in the rocks throughout the length and breadth of the series. *Characters* similar to these unite the strata of all the formations.

The character last mentioned we must refer to more particularly, on account of its great importance in designating with precision the group to which local and isolated beds of rock belong.

In defining the use of fossils it is stated that each formation has, in great part, its own fossils.

Most of those found in one do not occur in any other. Upon this fact depends their great utility. They furnish, when known well enough to be recognized, unmistakable evidence of the geological position, and hence the general character of the formation in which they are found.

From these observations of Prof. Safford we postulate the principles of correlation which he used, as follows:

I. Stratigraphic position.
II. The occurrence of similar fossils.
III. Lithologic characters.

CANADA.

The New York series was traced into Canada by Sir Wm. E. Logan and his associates and correlations made by direct stratigraphic connection, and in the absence of that, paleontologic data, stratigraphic relations, and lithologic characters.

Logan.—In speaking of the stratigraphic succession of the New York and Canadian sections Sir W. E. Logan makes the following reference to the fossiliferous limestone above the Calciferous sandrock, or the Trenton limestone:

The lowest of the fossiliferous strata is a sandstone of variable quality, more purely siliceous towards the bottom, and calciferous towards the top, which gives support to a thick and remarkably persistent deposit of limestone, strongly distinguished by its organic remains. This limestone thus becomes an admirable means of tracing

[1] A geological reconnaissance of Tennessee; first biennial report, Nashville, 1856, pp. 130, 131.

ont the perimeter of the great western area under consideration. From the northwest border of North Carolina it sweeps in a broad belt across Virginia to the junction of the Shenandoah and Potomac. Thence traversing Maryland, it passes through Pennsylvania by Harrisburg, on the Susquehanna, and Belvidere, on the Delaware, accompanied up to this point by the underlying sandstone. Diminished in its thickness, it thence crosses New Jersey, and reaching Poughkeepsie it passes up the valley of the Hudson and Champlain, keeping to the east of the river and the lake, and attains the neighborhood of Missisquoi Bay. Entering Canada, it proceeds towards Quebec, and it reaches the vicinity of that fortress; but I am not yet aware of the precise spots at which it is visible in its course thither, farther than that I have been informed a stratified limestone answering its condition is quarried and burned in the Seignory of St. Hyacinthe, east of the Yamaska River.[1]

He states that the city of Quebec does not stand on this limestone, but it is found below the city on the north shore of Beauport and farther down the river to Cape Tourment. Following up the valley of the St. Lawrence, it is found to run along the foot of a range of syenitic hills, and it leaves the river in the vicinity of Montreal and again appears in the Ottawa Basin. He then describes its extension south along the valley of Lake Champlain, and west through the valley of the Mohawk and Black River and north of Lakes Ontario, Huron, and Michigan, to Wisconsin, following thus the correlation made by Hall.

NEWFOUNDLAND.

The extension of the Canadian nomenclature to Newfoundland was the work of Messrs. Logan and Billings. In tracing the Paleozoic formations down the St. Lawrence River from Montreal, Logan found that a series of sandstones occurs beneath the Calciferous sandrock, which was well recognized beneath the Trenton limestone. The sandstones rested unconformably upon the subjacent Archean. A long interval exists between these exposures and those on the north side of the Straits of Belle Isle, where sandstones and limestones are superjacent to the Archean. In his first expression of opinion he calls the sandstones the Potsdam, from their stratigraphic position and lithologic character. When the fossils which were obtained from the associated limestones were examined by Mr. Billings and found to be identical with those that he had referred to the Lower Potsdam in Vermont, the strata on the north side of the Straits of Belle Isle were referred without reserve to the Potsdam horizon, and those occupying a similiar position on the west of Newfoundland were also similarly referred.[2]

When correlating the Lower Cambrian sandstones and slates of northern Vermont with the limestones and sandstones of the north shore of the Straits of Belle Isle, upon the lithologic and paleontologic similarities between the two deposits, Mr. E. Billings states that although 860 miles distant from each other there can be little doubt that they are of the same age.

[1] [Account of general structure of an extended area in North America.] Geol. Survey Canada, Report of Progress for 1843, 1845, p. 8.

[2] Geological Survey of Canada; Report of Progress from its commencement to 1863, pp. 97, 288, 289, 864, 865. Montreal, 1863.

The occurrence of *Scolithus linearis* and the general aspect of the fossils also show that these rocks must be very nearly, if not exactly, in the same geological horizon with the Upper Primal sandstones and slates of Pennsylvania.[1]

The Lower Paleozoic rocks of Newfoundland were correlated with those of Canada by Sir W. E. Logan upon the evidence of the fossils and their stratigraphic position. The fossils were identified by Mr. Billings, and the stratigraphic geology was studied by Messrs. Richardson, Murray, and Howley.

Dana.—Prof. J. D. Dana availed himself of the correlations made by the New York, Canadian, and other surveys in the preparation of the earlier editions of his Manual of Geology. The Manual is a masterly compilation of the available data upon broad principles of correlation, and as it went at once into the hands of all American geologists and students its influence has been widespread. The principles of correlation mentioned are outlined in the following paragraphs:

But the question may arise whether a geological age is not, after all, strongly marked off in the rocks. Rocks are but the moving sands or the accumulations of dead relics of the age they represent, and are local phenomena, as already explained. Each continent has its special history as regards rock-making, and it is only through the fossils in the rocks that the special histories are combined into a general system. Movements have in all ages disturbed one hemisphere without affecting the other, causing breaks in the succession of rocks in one continent or part of a continent that have no representatives in another.

When an age can be proved, through careful study, to have been closed by a catastrophe or a transition which was universal in its effects, the event is accepted as a grand and striking one in geological history. But the proof should be obtained before the universality is assumed. Hence the conclusion:

Fourthly. The grander subdivisions or ages in geological history based on organic progress should be laid down independently of the rocks. They are universal ideas for the globe. The rocks are to be divided off as nearly as practicable in accordance with them.

Each continent, under these ages, then becomes a special study, and its history has its periods and epochs which may or may not correspond in their limits with those of the other continents. Every transition in the strata, as from limestone to sandstone, clay beds or conglomerate, or from either one to the other, and especially where there is also a striking change in the organic remains, indicates a transition in the era from one set of circumstances to another; it may be a change from one level to another in the continents, a submergence or emergence or some other kind of catastrophe. All such transitions mark great events in the history of the continent, and thus divide the era into periods, and periods into epochs, and epochs, it may be, into subepochs. Hence—

Fifthly. Through the ages each continent had its special history; and the periods and epochs in that history are indicated by changes or transitions in the rock formations and their fossils.

It is greatly to the assistance of research that some of the revolutions of the globe have probably been nearly or quite universal. The one preceding the Mammalian age appears to be an example; although, even with regard to this, further investigation is required before its actual universality can be regarded as established. But the periods and epochs of America and Europe are not in general the same in their

[1] Paleozoic fossils. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. Vol. 1, 1860 1865, p. 2. Montreal, 1865. First printed in 1861 in a bulletin issued by the Geological Survey of Canada.

limits. A near contemporaneity in rocks may be proved, but not in the transitions from one rock to another. For example, the Devonian age has a very different series of periods and epochs in North America from what it has in Europe, and there is even considerable diversity between the epochs of New York and the Atlantic slope and those of the Mississippi Valley. The Carboniferous, Reptilian, and Mammalian ages also have their American epochs and their European, differing from one another; and the differences between the continents increase as we come down to more modern times. There are Tertiary and Cretaceous rocks in America as well as Europe, but there is little reason for the assumption that the transitions from one set of Tertiary or Cretaceous strata to another were, in the two, contemporaneous. The point should be proved, not assumed. We add, therefore,

Sixthly. It is an important object in geology to ascertain as nearly as possible the parallelism between the periods and epochs marked off on each continent, and study out the precise *equivalents* of the rocks, each for each, that all the special histories may read as parts of one general history, and thus contribute to the perfection of one geological system.[1]

MISSISSIPPI VALLEY.

The Lower Paleozoic rocks of this region were correlated with those of New York by Messrs. Owen, Locke, Hall, and others, usually without stating the data except by implication (e. g., speaking of the Trenton limestone of New York as a limestone carrying certain fossils and superjacent to a marked formation, the Calciferous sandrock of New York or the Lower Magnesian limestone of Wisconsin, etc.). Thus the correlation is based upon stratigraphic position, presence of similar fossils, and lithologic characters.

Hall.—The following observations by Prof. Hall are a good illustration of the method by which the Potsdam sandstone of New York was correlated with the lower sandstone of the Mississippi Valley section:[2]

In comparing the older rocks of New York and of the East generally with those of the West it should not be forgotten that there is a long interval on the line of the northern outcrop of these ancient strata between the St. Lawrence and the western limit of Michigan on the Menomonee River, where we can expect little aid from paleontology. The fossiliferous beds of these ancient formations in Wisconsin lie to the west of what appears to have been a great promontory at the time of their deposition, stretching southward from the region of Lake Superior far into the ancient sea. The disconnection caused by this promontory between the East and the West would of itself prepare us to expect a fauna differing in a great degree from beds of corresponding age on the opposite sides.

It has been shown by the investigations of the Canadian Survey that not only the Potsdam sandstone but all the fossiliferous beds below the Birdseye and Black River limestones are absent from Kingston, on Lake Ontario, to Lacloche, on lake Huron. From Lacloche to Lake Superior there is a sandstone coming in below the Birdseye limestone, which, from its position, may be considered as of the age of the Chazy[3] for-

[1] Manual of Geology, 1st ed., New Haven, 1863, pp. 126–128.

[2] Preliminary notice of the fauna of the Potsdam sandstone, with remarks on the previously known species of fossils and descriptions of some new ones from the sandstone of the Upper Mississippi Valley. 16th Ann. Rep. Reg. State Cab., Nat. Hist. N. Y., 1863, pp. 211–213.

[3] The 'Chazy formation' of the Canadian Geological Survey, in its eastern localities includes a sandstone which comes in below the greater part of the limestone, leaving from 10 to 20 feet of shale and limestone beneath (Geology of Canada, 1863, p. 123). It is apparently this sandstone of the Chazy formation, having in Canada a thickness of 50 feet, which has become augmented in its western extension while the calcareous part of the formation has partially or entirely disappeared.

mation and equivalent to the St. Peters sandstone of Wisconsin and Minnesota, and it is this sandstone, doubtless, which has been taken for the Potsdam sandstone in some localities along that line.

The succeeding Birdseye and Black River formation from Lacloche to Lake Superior has become a buff-colored magnesian limestone, or weathering externally to this color, but still holding the characteristic fossils.

In New York a sandstone (the Potsdam) lies immediately beneath a magnesian limestone (the "Calciferous sandrock"); this deposit is succeeded by a calcareous formation (the Chazy), including a sandstone and surmounted by the Birdseye, Black River, and Trenton limestones.

In Wisconsin, Iowa, and Minnesota we have undoubted Trenton limestone, and below it a buff-colored magnesian limestone containing so many of the characteristic fossils of the Birdseye and Black River limestones as to leave no doubt of the parallelism of these beds with those of New York. Below this magnesian limestone we have the St. Peters sandstone, corresponding, as already shown, with the Chazy formation, and beneath this a magnesian limestone, which, in its position and lithological character, corresponds in all respects with the "*Calciferous sandrock*" of New York.

It is from all these facts that the lower sandstone of the Upper Mississippi Valley has been placed in parallelism with the sandstone of New York known as the "Potsdam."

Notwithstanding, however, that this sequence is precisely like that observed in New York it may not yet be regarded as proved that the sandstone from which I have described these fossils is in all respects the equivalent of the Potsdam sandstone of New York, Vermont, and Canada. It may represent more or it may represent less than that formation. The *lower* accessible beds of the Mississippi Valley may represent the Potsdam of 150 or 200 feet in thickness in the typical localities in New York, while the middle and upper beds of the West may be of epochs not represented in that part of the series studied in New York; and in some other places, as in the regions just mentioned, the same epochs may be represented by a shaly or semi-calcareous deposition, or may be included in the commencement of the Calciferous epoch. It should not therefore be regarded as decided that the Potsdam sandstone, as developed in New York, occupies the entire interval from the base of the oldest sedimentary formation of the Paleozoic era to the Calciferous sandstone. From what we know of the Primordial fauna in other localities we are prepared to find beds above or below, or both above and below, the epoch represented (so far as now known) by the Potsdam sandstone of New York, and which may still be of the same period.

Winchell.—It is stated by Prof. N. H. Winchell that—

It has been abundantly proved that the red sandstones of Lake Superior, however disturbed and changed locally, or however much increased in thickness by the agency of volcanic outbursts, are the exact equivalents of the New York *Potsdam*. They occupy the first position over the metamorphic slates of the *Huronian* rocks on which they lie unconformably, and from which they differ in being but slightly and only locally metamorphosed. They retain usually their evidently sedimentary characters, and have not well preserved fossil remains.[1]

He also publishes a table showing the number of species common to various Silurian formations of the Lake Superior district and New York State, and calls attention to the fact that three species only are found in the Lake Superior sandstone and the typical Potsdam sandstone of New York.

[1] General sketch of the geology of Minnesota. Geol. and Nat. Hist. Survey, Minnesota, 1st Ann. Rep. for 1872, 1873, p. 68.

The correlation by Prof. N. H. Winchell of the "Granular Quartz" and the "Red sandrock" of Vermont with the "Potsdam" sandstone of the Upper Mississippi Valley and the "Primordial" quartzite of the Northwest appears to be based upon the fact that the "Granular Quartz" of Vermont and Massachusetts rests unconformably upon the Archean, and that a similar quartzite is superjacent to Archean rocks in the Mississippi Valley. This same principle of correlation appears in his statement that the stratigraphic relations of the "Granular Quartz" and the Potsdam of New York are the same. He says: "In the first place, they are seen to lie unconformably upon the older granite."[1]

Messrs. N. H. Winchell and H. V. Winchell correlated the Winooski marble series of Vermont with the Stockbridge limestone or marble belt of the southwestern portions of the State.[2]

This correlation is based upon (*a*) the assumed Primordial age of the iron-bearing limestones and shales of the Penokee-Gogebic range of Wisconsin and the Mesabi range of Minnesota, and their assumed stratigraphic identity with the limestones and shales of western Vermont, which correspond to the Stockbridge limestones and iron ores of western New England; (*b*) the known Cambrian age of the Winooski marble series.

Meek.—As paleontologist of the Hayden and other surveys of the interior and western continental area, Mr. F. B. Meek's influence upon the correlation of fossiliferous strata was important. His views upon correlation by paleontologic evidence are given in a report on the Paleontology of eastern Nebraska, as follows:[3]

> There are probably few well informed geologists who will at the present time maintain that the occurrence of a very similar or even the same group of fossils at widely separated localities necessarily proves the rocks in which they are found to be of exactly contemporaneous origin. The most that is now generally maintained in this regard is that such identity or correspondence of types at very distantly separated parts of the world indicates that the strata in which they are imbedded were formed during the prevalence of identical or similar physical conditions at some time during the same great geological epoch, and that they hold the same or nearly the same *relative* position in the geological column of their respective districts. For instance, although a stratum in the Rocky Mountains, containing the remains of very nearly the same fauna as some particular subdivision of the Devonian system of Europe, might, for aught we know, be hundreds of years older or newer than that particular division, we would have little or no room for doubting that it belonged to the great Devonian series, or possibly even to some definite, known horizon in that series. We could moreover very positively assert in such a case that it would be, according to all past experience, useless to seek there at any lower geological horizon for workable beds of coal, or to expect to find Silurian rocks or any of their pe-

[1] The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist. Survey of Minn., 17th Ann. Rep. for 1888, 1889, p. 49.

[2] The Taconic Iron Ores of Minnesota and Western New England. Am. Geologist, vol. 6, 1890, pp. 263 274.

[3] Report on the Paleontology of eastern Nebraska, in Final Rep. of U. S. Geol. Surv. of Nebraska, Washington, 1872, p. 83.

culiar products above, supposing there had been no overturning of the strata at the particular localities.

Hence, although paleontology does not enable us to ascertain the exact *actual* ages of rocks, when applied with due caution and skill in connection with a careful observance of their stratigraphical arrangement and lithological and other physical characters, it does afford the means of fixing their *relative* ages, as well as of identifying the same beds at different localities, within given fields of observation, with very considerable precision. It is therefore not merely *one* of the more important aids to the geologist in his investigations, but in the present state of geological science it is the only sure guide in classifying and determining the order of succession of rocks where this can not be done by their actual continuity or obvious superposition. For these reasons it is now the universal practice in all geological surveys conducted upon sound scientific principles to devote especial attention to this department.

ROCKY MOUNTAINS.

Whitney.—In speaking of the occurrence of the Primordial fauna in Nevada Prof. J. D. Whitney calls attention to the fact that the fossils are of Potsdam age, and that similar trilobites and brachiopods occur in Bohemia in argillaceous shales; throughout the United States, from New York to the Rocky Mountains, in the "Potsdam sandstone, or in the shales or slates;" in Texas and in Nevada, in limestone. He says:

This discovery will also indicate the necessity of caution in theorizing on the geological structure and age of regions which have only been hastily examined. It will not do to put down every red-sandstone group below the Trias in the far west as "Potsdam," for that subdivision may be much lower down, hiding itself as a modest limestone of a very neutral tint of color.[1]

Although not stated, it is evident that the principle of correlation used is purely biologic, or the occurrence of similar fossil remains.

Bradley.—When describing the strata upon the western base of the Wasatch range, near Ogden, Utah, Prof. F. H. Bradley refers the quartzite, some 1,500 feet in thickness, to the Potsdam, and the gray and calcareous shales and limestones above to the Upper and Lower Silurian.[2] A reference to the Upper Silurian was on the assumption that the limestone was the same limestone as that found 25 miles to the north, in which the characteristic Niagara coral *Halysites catenulata* was obtained by Dr. Hayden in 1871. The data upon which the other correlations are made are not given. It is probable and almost certain that the presence of a quartzite beneath the limestone, supposed to be of Silurian age, was considered to be sufficient for the reference to the Potsdam sandstone. He correlates the glauconite sandstone beneath the limestone of the Teton range section, which carries Conocoryphe and Dikelocephalus, with the Knox sandstone of Safford, in Tennessee. Beneath them, and often present when they are absent, he found from 50 to 75 feet of a very compact ferruginous quartzite "which must represent the Potsdam."[3]

[1] Note on the occurrence of the "Primordial Fauna" in Nevada. Am. Jour. Sci., 3d ser., vol. 3, 1872, p. 85.

[2] Report of Frank H. Bradley, geologist of the Snake River Division. U. S. Geol. Sur. of the Terr., 6th Ann. Rep. 1873, p. 194.

[3] Op. cit., p. 216.

It is evident that Prof. Bradley had in mind the Tennessee section, with which he was familiar, and on finding a quartzite, corresponding to the Chilhowee quartzite, and then a sandstone and shale corresponding in position to those of the Knox section, he correlated the two upon the evidence of serial relation of similar deposits and the presence of certain fossils in the limestone superjacent to the sandstone.

Fortieth parallel survey.—The correlations made by the fortieth parallel survey of the Paleozoic rocks of Utah and Nevada with those of the eastern part of the continent, especially the New York section, are based almost entirely upon the paleontologic evidence as determined by Messrs. Hall and Whitfield. Within the area of the survey correlations were made both on the stratigraphic succession of beds of different lithologic character, and the presence of similar organic remains. A correlation based on the "likeness of two great masses of rock to each other that occur beneath a known horizon" is made by Mr. Clarence King as follows:

> Comparing the quartzites and argillites with those of the Cambrian section in Wales, the likeness is too great to pass unnoticed, and in view of the enormous developments of these low-lying rocks as compared with the Silurian lying above the Primordial horizon, I have determined to draw a line at the upper limits of the Primordial period to include the uppermost members of the Potsdam epoch, and to consider the whole underlying conformable series as Cambrian down to the point of their nonconformity with the Archean.[1]

Explorations and surveys west of the one hundredth meridian.—The correlations made in the publications of this survey on the Lower Paleozoic rocks are mainly by Mr. G. K. Gilbert in his report on the geology of portions of Nevada, Utah, California, and Arizona.[2] The data used for correlation are, the stratigraphic position, lithologic characters, and the presence of fossils of previously determined range. No attempt is made to correlate by a study of the minor details of the faunas and strata except in the correlation of the Tonto of the Grand Cañon district with the Primordial formations of the East. From the known position of the genus Cruziana he argues that the beds containing it are Lower Silurian or Primordial. Mr. F. B. Meek compares the species of Olenellus found in central Nevada with *O. thompsoni* and *O. vermontana* of Vermont and thus indirectly correlates the faunas.[3]

Geological surveys of the Territories.—The correlations made by the various writers of the Powell and Hayden surveys were principally based upon the paleontologic determinations of Mr. F. B. Meek and Dr. C. A. White outside the territory of the survey, and within its territory on stratigraphic positions, lithologic character, and fossils when present. In most instances the data for correlation are not given, the identification of the formations following that of previous workers in the same territory. An example of this is found in the "Geology of the

[1] Paleozoic subdivisions on the 40th Parallel. Am. Jour. Sci., 3d ser., vol. 11, 1876, p. 476.
[2] Expl. and Surv. West of 100th Merid., vol. 3, 1875, pp. 156–171.
[3] Op. cit., pp. 182, 183.

Black Hills of Dakota," where a sandstone characterized by Upper Cambrian fossils is identified without comment as the Potsdam sandstone.

U. S. Geological Survey.—In the consolidation of the various Government surveys and their reorganization under one head in 1879 the opportunity for broad comparisons and studies was increased, and the opportunities were still further increased in 1881, when the survey was extended to include the entire area of the United States. In the Rocky Mountain Province the correlations of the fortieth parallel survey were accepted, and extended in the abstract of the report on the geology of the Eureka district of Nevada.[1] In the report on the paleontology of the district the paleontologic data upon which the correlations were made are assembled and described.[2] In this it is shown that while correlations between the great groups may be extended between the Appalachian Province and the Rocky Mountain area, it is impossible to correlate the minor divisions of the groups.

In 1886 an extended correlation of the rocks and fossils from the Lower Cambrian, then called Middle Cambrian, was published in Bulletin No. 30 of the U. S. Geological Survey.[3] Typical sections are given of the Cambrian rocks of the Atlantic Coast, Appalachian, and Rocky Mountain Provinces, with the names of the species of fossils occurring in the various zones, and on page 44 the various sections are correlated and grouped in a table to show their relative range. The principles of correlation are not enunciated, but those used, as shown by the text, are the stratigraphic position of the faunas in relation to each other in the same province and a comparison of the faunas in one area with those of another.

In a more recent work[4] the correlations are made between the various horizons of the Cambrian of the United States on the stratigraphic position of the strata and the occurrence of similar groupings of organic remains. It is observed that the presence of the Olenellus fauna is regarded as the strongest factor in the correlation of the Lower Cambrian, and it is assumed that the presence of this fauna indicates the same geologic horizon. It is not implied that the formations characterized by the Olenellus fauna are strictly contemporaneous wherever it has been found. On the contrary, its presence in such widely separated localities as England, France, Spain, Nevada, and British Columbia is considered as prima facie evidence that the deposits are not strictly contemporaneous. That they were contemporaneous in a geologic sense or that they occupy the same relative position in the geologic series is accepted throughout the paper.

[1] Third Ann. Rept. U. S. Geol. Survey, 1883, pp. 248–272.

[2] Mono. U. S. Geol. Survey, vol. 8, 1884.

[3] Walcott, C. D.: Second contribution to the studies of the Cambrian faunas of North America. 1886.

[4] Walcott, C. D.: The fauna of the Lower Cambrian or Olenellus zone. Tenth Ann. Rept. U. S. Geol. Survey, 1890, pp. 509–763.

In his extended and valuable essays upon the history of the names Cambrian and Silurian in geology and the Taconic question in geology, and numerous other minor papers, Dr. T. S. Hunt[1] clearly sets forth the description of the various strata referred to the Cambrian and Silurian in America and Europe, and shows by testimony of different writers the relations the various formations sustain to each other, both stratigraphically and in their geographic distribution. Nearly all, if not all, the original correlations made by him are based upon lithologic data, as he believes in a uniform development and sequence of lithologic forms from earlier Archean time to the deposition of the fossiliferous sedimentary rocks. The correlations within the latter are largely made upon their stratigraphic, lithologic, and paleontologic characters as mentioned by authors.

CORRELATIONS WITH EUROPEAN FORMATIONS.

Numerous correlations were made between the strata of the formations of America and those of Europe by Messrs. Conrad, Owen, Rogers, Troost, Jackson, and others; but it was not until the investigation of M. Edward de Verneuil, in 1847, that correlations were made by one who had personally investigated the formations and fossils, both in Europe and America.[2]

De Verneuil.—He began his comparisons with the view that superposition was the foundation of paleontology; that the only comparisons that could be made between continents separated by a sea was by a study, in each of them, of a series of beds confined between two zones at well determined points; that their fossils must be compared, and the identical species picked out to see if the species are distributed according to the same laws. He concluded that, if it happens in the two countries that a certain number of systems, characterized by the same fossils, are superimposed in the same order, whatever may be otherwise their thickness and the number of physical groups of which they are composed, it is philosophical to consider these systems as parallel and synchronous. Comparisons were made between the strata in the two countries that occur beneath the coal-bearing or Carboniferous rocks. He noted that the Potsdam sandstone with Lingula is probably analogous to the sandstone with Obolus, of Russia, and the lower sandstones of Scandinavia. "These are in the two continents the most ancient pre-Carboniferous rocks."

The *siliceous* limestones, those of Black River and of Trenton, are the equivalents of a great part of the Lower Silurian stage of Europe, and they occupy the same posi-

[1] History of the names Cambrian and Silurian in Geology. Canadian Nat., new ser., vol. 6, 1872, pp. 281–312, 417–448. The Taconic Question in Geology. Mineral Physiology and Physiography. A second series of Chemical and Geological Essays. 1886, pp. 517–686.

[2] Note sur le parallélisme des roches des dépôts paléozoïques de l'Amérique Septentrionale avec ceux de l'Europe, suivie d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des étages ou elles se rencontrent, et terminée par un examen critique de chacune de ces espèces. Soc. géol. France, Bull., 2e sér., vol. 4, pp. 646–709, 1847. Translated and condensed by Prof. James Hall. Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 176–183, 359–370; vol. 7, 1849, pp. 45–51, 218–231.

tion as the bituminous schists and the Orthoceratite limestones of Sweden and Russia. The Utica slate and the Hudson River group, with the Graptolites at their base, represent the Graptolite slates which in Sweden succeed to the red Orthoceratite limestone. They are also the same as those of Bain in France.[1]

Of the Upper Silurian rocks the Niagara group is considered the exact equivalent of the limestones and slates of Wenlock and of Gothland. The Clinton group, with *Pentamerus oblongus*, represents the extreme upper part of the Caradoc sandstone, or a stage intermediate between the Wenlock and Caradoc beds; while the five inferior groups of the Helderberg division represent the rocks of Ludlow. The correlation is then extended to the Devonian, and lists are given of identical species of fossils on the two continents.

Hall.—The essay of M. de Verneuil was followed in 1851 by a paper on the "Parallelism of the Paleozoic deposit of the United States and Europe," by Prof. James Hall. In discussing the criteria of correlation he says:[2]

The simplest principles of elementary geology teach us that sedimentary beds, having the same thickness and the same lithological characters, can not have spread over an area so wide as that now included between the European and American continents. All sedimentary deposits must vary in character at remote points, as the physical conditions of the ocean can not be presumed to have remained the same over a wide extent of surface. Under such circumstances absolute parallelism is not to be sought for or expected. Calcareous deposits, as would naturally be supposed, have been found to be more persistent and more uniform in the character of their fossil contents; but these, over some portion of their extent, have often been invaded by argillaceous and arenaceous sediments, and the fauna is found to be in a greater or less degree influenced by such circumstances. In distant and disconnected localities we are compelled to base our opinions of the equivalency of beds upon the organic remains which they contain; and when we reflect that the nature of the sediment may in a great degree influence the character of the fossils we shall not fail to recognize the necessity of keeping the character of these lithological changes in view. * * *

Besides the changes which take place in the nature of the sediment deposited upon the bed of the ocean, we are to look to other important conditions which may affect the fauna, and consequently our conclusions regarding the equivalency of formations. Among the most important of these is the depth of the ocean in which the animals lived, since we know that certain species are confined within certain zones, depending on the depth of the water.

There are other conditions which sensibly affect the distribution of organic life, such as temperature, pressure, and light. * * * In investigating the fauna of past ages we see nothing to lead us to believe that the same great laws which regulate the distribution of species did not then operate with as great effect as at the present time.

In speaking of the attempted correlation between the European and American rocks Prof. Hall remarks:

All the attempts to show that the parallelism of American and European paleozoic deposits have been with a view to find a correspondence with the European standard where the series is confessedly incomplete, and where it has suffered during its deposition, or subsequent to it, many disturbances.[3]

---

[1] Op. cit., p. 361.

[2] Report on the Geology of the Lake Superior Land District, by J. W. Foster and J. D. Whitney; Part II, 1851, pp. 286, 287.

[3] Op. cit., p. 294.

The author agrees with M. de Verneuil that the Potsdam sandstone is represented in Russia by the beds containing Obolus and Lingula, and in Scandinavia by the sandstones which rest unconformably upon the gneissoid and schistose rocks composing the Azoic system. Of the Chazy, Birdseye and Black River limestones of New York he says:

> They are not very clearly recognized in Europe. It is probable that some part of the Orthoceratite limestone of Sweden is the equivalent of the Black River mass; but we have no evidence, from fossils or otherwise, that there are any representatives of the two lower rocks. * * *
>
> The Trenton limestone, the Utica slate, and the Hudson River group are represented in northern Europe by the Orthoceratite limestone of Sweden and Russia and by the shales with Graptolites, which succeed to that limestone. In Great Britain the Llandeilo flags and Caradoc sandstone are clearly the equivalent of these groups. It is here that we first find a number of species identical with European ones, and which enable us to institute a comparison. It will be found, however, that the species in the Hudson River group correspond most nearly with the European forms, and that it may be doubtful if the base of the Trenton limestone has been reached in Great Britain.[1]
>
> The Clinton group, with its beds of *Pentamerus oblongus*, represents what in England is regarded as the upper part of the Caradoc sandstone; but we find it not only above this well marked horizon, which we have already indicated, but associated with numerous species of fossils, some of which are known as upper Silurian forms in Europe, and others pass into forms characteristic of the Niagara group in this country.
>
> The Niagara group, with its shale and limestone, would seem, at first view, to be the exact equivalent of the shale and limestone of Wenlock and Dudley in England, and of Gothland in Sweden, so numerous are the identical species in these groups; but on examination we find that there are numerous species included in these rocks in Europe which occur only in the lower Helderberg limestones, and which are separated from the Niagara by the enormous deposit of the Onondaga salt group. It is clear, therefore, that in the Wenlock formation of England and its representatives in northern Europe are included parts at least of two distinct groups in the order of time—distinct both in their physical and zoological features; and we can not institute a proper comparison between the rocks of our own country and those of Europe while we regard that as one group. The condition, both in England and on the continent, is doubtless similar to what we find in Tennessee and Virginia, where, from the absence of the intermediate groups not only the Niagara and lower Helderberg are united together, but even the upper Helderberg limestones are superadded.[2]

Barrande.—A correlation based upon paleontologic data was made by Mons. J. Barrande, in 1853, between the formations characterized by the first, second, and third faunas of Europe and those included in the Silurian of America. In commenting upon the identification of the Russian *Obolus apollinis* Eichwald, by Owen, with the Potsdam sandstone species of the Upper Mississippi Valley, he says:

> In fact I am inclined to think that science has passed out of the epoch when it was thought necessary to have identical species in order to recognize equivalence of geologic horizons, even at great distances on the earth's surface. The distribution of our present fauna teaches us that this means can not be altogether relied on to prove strata contemporaneous.[3]

---

[1] Op. cit., pp. 295, 296. [2] Op. cit., p. 299.

[3] Barrande, J: (Silur-fauna in Wisconsin und in New York.) Neues Jahrbuch für Miner., 1853, p. 338.

The fact that the Paleozoic formations of America during the appearance and disappearance of three successive faunas, which despite some common species are on the whole well distinct, teaches us that the extinction and appearance of beings on the earth's surface are by no means determined exclusively by the physical revolutions of the crust, but are ordered and regulated by the laws of animal creation itself. Still, it is not my intention to follow out this consideration, as it would lead me too far. I merely wished to mention this, in passing, as a subject for further study, and to point out to investigators that paleontology leads to the establishment of a geologic chronology, independently of the more or less local revolutions which the fossiliferous strata have undergone since their deposition.[1]

From a study of the faunas of the two countries he considered that the first, second, and third faunas of Bohemia are to be identified in America; that there exist manifold relations in all classes of animals of the Upper Silurian division of the United States and Bohemia; that, in the first volume of Hall's Paleontology of New York, on the Lower Silurian division, from the Potsdam sandstone to the Hudson River group inclusive, he recognizes the First Silurian fauna of Bohemia, Sweden, and England; that the presence of the long-missed first fauna of Bohemia in America has been demonstrated in a very satisfactory manner by Owen in his discoveries in the northwestern United States; and that the occurrence of this fauna in the State of Georgia is indicated by a Conocephalus brought to England. In conclusion, he says:

Hence I am now perfectly convinced that the Silurian formations of North America, as well as those of the old continent, contain a succession of three different faunas, which, on being separately compared with the latter, are seen to consist of the same geologic elements and to follow each other in the same order. When I say that they consist of the same geologic elements you know already that I am far from wishing to maintain identity of species. I rely on other more general analogies which to me are not less convincing. This is not the place to explain this more in detail, as that would lead me too far; but you will find here and there in my work some passages which express my view of the matter. In admitting and recognizing in all Silurian regions of the two continents three general faunas corresponding and equivalent to each other, I am induced by the facts to pronounce a further result of my investigations, namely, that the local divisions of strata containing these great faunas, though greatly differing from each other in each region of a certain extent, are not equal to each other in the various countries, especially when the countries are far apart, geographically. This truth seems to me solidly established by a multitude of facts which are tabulated and compared in my geologic sketch, and is confirmed in a very satisfactory manner by the facts mentioned in volume 2 of J. Hall's Paleontology of New York.[2]

Rogers.—In a paper read before the British Association for the Advancement of Science in 1856, on the correlation of the North American and British Paleozoic strata, Prof. Henry D. Rogers described the Paleozoic section of the Appalachian region and that of England, and instituted comparisons between them, to show the parallelism of the North American and European Paleozoic rocks.[3] He says:

In attempting this correlation it should be remembered that nature represents no true or literal equivalency of strata, nor anything closer than a mere approximate

[1] Op. cit., p. 339.

[2] Op. cit., p. 345.

[3] On the correlation of the North American and British Paleozoic strata. British Assoc. Adv. Sci., vol. 26, 1857. Trans. Sec., p. 184.

relationship where the deposits compared belong to independent basins, or even to the remote sides of the same great receptacle. The most we can hope to establish is a general agreement in time, with possibly a stricter synchronism of the few chief paroxysmal movements which agitated the bed of the ancient ocean. Partially *representative* formations are discoverable, but *equivalent* ones are not to be looked for upon any philosophical view, since the distribution of organic beings is essentially partial or geographical. The life horizons of the globe are no more universal than are its horizons of sedimentation. With these reservations we turn to the degrees of affinity, linking the American and European Paleozoic groups of fossils.

As the result of his correlation he concludes:

(*a*) The Appalachian Primal series is obviously nearly on the horizon of Barrande's Primordial zone and the lowest rocks of Russia and Scandinavia.

(*b*) The Appalachian Auroral strata may possibly be approximately contemporaneous with the Swedish Orthoceratite limestone. The Auroral series includes the Calciferous, Chazy, and Black River groups.

(*c*) The Matinal series of the Trenton and Hudson River groups, from the testimony of the fossils, are represented in Britain by the Llandeilo flags and Caradoc sandstone, or more generally by Sedgwick's Bala or Upper Cambrian group. He also finds a near equivalent in the Orthoceratite limestone of Sweden and Russia and in the Graptolite shales. The authority of Prof. Hall is cited to show the paleontologic similarity of the English and American formations.

(*d*) The Levant or Medina group does not appear to be represented in Europe.

(*e*) The Surgent and Scalent series, or Clinton and Niagara, are compared with the British Wenlock strata.

(*f*) The Pre-meridian series or Lower Helderberg. He quotes Mr. Hall as saying that he agrees with Mr. Sharpe and regards the Lower Helderberg strata as representing the Wenlock formation of England, while M. de Verneuil considers them as equivalent to the Ludlow. He then proceeds to correlate the Devonian formations with those of Europe.

His final conclusion is:

> From all the foregoing facts and statements we arrive at this general inference, that upon both paleontological and physical evidence there is no well marked Silurian-Devonian break discernible in the North American basin, no proof of an epoch or general interruption in the life-stream, with wide crust disturbance in the middle Paleozoic ages, such as that which in earlier times, in the morning of the Paleozoic day, at the Cambro-Silurian transition, revolutionized alike the entire extent of the American and European areas, both in their inhabitants and in their physical geography.[1]

Bigsby.—A most elaborate comparison and correlation between the Paleozoic section of New York and that of Wales was made by Dr. J. J. Bigsby in 1859. He observes that "both these geological areas appear to have been constructed on the same great comprehensive principles and nearly of the same material, two most important considera-

[1] Op. cit., p. 186.

tions. One very great distinction between them, however, is that they have received different dynamic treatment, in the frequency of plutonic disturbance in Wales and its comparative absence in New York, such dynamic treatment involving, it must be kept in mind, both gradual and sudden changes of population. While the strata of these areas are formed of much the same mineral substances, the conditions of these, their order, and quantities are very varied."[1]

He sums up the points of zoological similarity under the following heads:

(1) The organic remains of both basins belong to the same orders and genera, unmixed with those of other sedimentary systems, as Permian, Jurassic, etc.

(2) Vertebrate animals were introduced at nearly the same date.

(3) The organic remains approximate closely in general facies.

(4) They affect strata of the same mineral character in both, the majority preferring the calcareous, the others the arenaceous form of deposit.

(5) The great majority exhibit the same order in their introduction and distribution. This is seen in Orthis, Pentamerus, Spirifer, and other Brachiopoda, and in Endoceras, Graptolites, Trilobites, etc., the more highly organized being often prominent in the early stages.

(6) The law of divergency into several matrices is the same, or nearly so, in the two basins, the number of instances being fewer in New York.

(7) The great majority of animals typical or recurrent in one basin are so in the other.

(8) The great majority of the recurrent fossils in both occupy the same number of epochs, many or few.

(9) The great majority observe the same process or law of increment and decrement. This takes place in nineteen out of twenty-four orders and genera.

(10) The two basins have 108 organic forms in common, including most of the genera.

(11) The same orders and genera are rich and poor in species.

(12) There is the same limited admission of Silurian forms into the Devonian system in New York and in Europe.

(13) The plants of both are typical, with one or two exceptions.

Such are some of the great points of similarity. Now as to dissimilarity. Those which arise out of the mineral character are partly owing to physical disturbances and to a certain amount of metamorphism undergone by the Welsh strata. The paleontological differences are many, but small, often merely individual, and they seldom affect principles. They are due to the varying sea depths and other well known conditions.

The facts just recorded certainly indicate a close connection in nature and mode of formation between the basins of New York and Wales. They seem to be quasi-equivalents—the same, but other, to use a short, but convenient phrase in common use.[2]

Agassiz.—When commenting upon correlations made between the Paradoxides zone of Newfoundland, Massachusetts, and Scandinavia, Prof. Louis Agassiz said:

That there may be synchronism of deposit without identity of fossils must be evident if we glance at the present distribution of animals. If at the present epoch the fauna of America and Australia should become fossilized there would not be the slightest resemblance between the representative species of the two continents. The

[1] Quart. Jour. Geol. Soc., London, vol. 15, 1859, p. 292. [2] Op. cit., pp. 292, 293.

paleontologist must be ready to admit that very different fossil faunæ may be contemporaneous, and that their difference does not necessarily imply a distinct zoological age.[1]

When discussing the typical forms and the distribution of the rocks of the Cambrian, Mr. J. J. Bigsby presents a table showing the order of succession of the Cambrian rocks in various countries.[2] In this he includes the Upper Cambrian sandstones of Texas and Nebraska, and they are referred to the upper or Primordial division of the Cambrian.

Matthew.—During the progress of his extended researches in the faunas and rocks of the Cambrian system in New Brunswick, Mr. G. F. Matthew has had frequent occasion to compare the stratigraphic succession and the faunas of the Cambrian of New Brunswick with that of Europe.

In a paper read before the British Association for the Advancement of Science in 1884, he correlates the fauna of the St. John group of New Brunswick with that of the Cambrian of Wales, and concludes that it shows closer relations with the Solva group than with the Menevian.[3]

Near the close of the same year he stated in a paper read before the Natural History Society of New Brunswick that the discovery of a higher fauna enabled him to correlate the beds containing it with the Menevian group of Wales.[4]

In an essay on the classification of the Cambrian rocks in Acadia,[5] Mr. Matthew considers that the Potsdam sandstone is equivalent to the Ceratopyge limestone, or the Tremadoc group, and represents the upper part of the Tremadoc, as the Georgian series probably does the lower. This correlation is made upon the interpretation of the characters of the genera of trilobites in the American and European rocks.

A second paper on the classification of the Cambrian rocks in Acadia appeared in 1889, in which a comparison of sections in Sweden and New Brunswick with the characteristic sections of Cambrian rocks in Europe and in North America is made.[6] In the comparison of sections of Sweden and New Brunswick the base of the Paradoxides beds is taken as the datum point and it is shown that the pre-Paradoxides horizon is present both in Sweden and New Brunswick, and that the Upper Cambrian or Olenus horizon is represented in New Brunswick by Stage 2 of the St. John County section and by the same stage in Sweden. In the second table of the sections of the Cambrian rocks in Europe and in North America, the correlations made between the sections of Sweden and New Brunswick are accurate and valuable; but those between the

[1] On the difference between faunas of zoological and geological periods. Boston Soc. Nat. Hist., Proc., vol. 8, 1862, p. 58.

[2] On the Cambrian and Huronian formations. Geol. Soc. Quart. Jour., London, vol. 19, 1863, p. 44.

[3] The geological age of the Acadian fauna. Brit. Ass. Adv. Sci., Rep. 54th meeting, 1884, pp. 742, 743.

[4] An outline of recent discoveries in the St. John group. Nat. Hist. Soc. N. B., Bull, No. 4, 1885, p. 101.

[5] Canad. Rec. Sci., vol. 3, 1888, pp. 79, 80.

[6] Canad. Rec. Sci., vol. 3, 1889, pp. 308–311.

western North American sections of the Wasatch, Nevada, Highland Range, and Eureka are more or less defective, owing to the imperfect interpretation of the paleontologic data.

The next essay upon the correlation and comparison of the European formations with those of America by Mr. Matthew is entitled: "How is the Cambrian divided?—A plea for the classification of Salter and Hicks."[1] He institutes comparisons of the strata in Wales, Newfoundland, and Norway, and of the characteristic trilobitic genera of each horizon. From the results obtained by these comparisons he considers that the Cambrian is to be divided into the Upper and Lower, and that the method proposed by Mr. C. D. Walcott, of separating the Olenellus or Lower Cambrian from the Paradoxides or Upper Cambrian, is not justified by the evidence afforded by the American and European sections.

METHODS OF CORRELATION.

I. Superposition.
II. Organic Remains.
III. Lithologic Characters.
IV. Unconformity.
V. Miscellaneous.

I. SUPERPOSITION.

(*a*) The order of superposition of strata is the foundation of geologic chronology. By its aid the stratigraphic succession and serial relations of the fossil faunas are first determined. Undisturbed superposition within a section is an absolute test of relative age of the parts of that section; it is not positive evidence of the age of the various beds in relation to beds sustaining the same serial relations in some disconnected section without other tests to support it, even though they occur in the same geologic province: e. g., a band of sandstone beneath a limestone and above a shale may be identified in one portion of a geologic province; but the occurrence of a band of sandstone beneath a limestone and above a shale, in a distant portion of the same province, is not positive evidence that the two bands of sandstone are synchronous or portions of one continuous formation, unless their continuity can be traced.

(*b*) Superposition is not a test of identity of formation except in a limited basin, where the geologist has evidence to show that the formation is practically continuous in its stratigraphic relations. In widely separated portions of the same basin, or of different basins, the order of superposition must be sustained by other tests before it can be asserted positively that the formations thus correlated are identical.

(*c*) In the same geographic or geologic province, fresh-water and marine deposits are not to be correlated with each other, even if they

[1] Am. Geologist, vol. 4, 1889, pp. 139–148.

have the same order of superposition, as the conditions under which they were accumulated are entirely dissimilar, and the proof of the contemporaneity of deposition is not available. An exception to this may occur where a stream passes through a lake and carries the fauna and flora to the sea, where it is mingled with the marine fauna.

II. ORGANIC REMAINS.

There are several considerations always to be borne in mind in correlating a formation on the evidence of its contained organic remains:

(*a*) There can be no scientific or systematic paleontology without a stratigraphical basis.[1]

(*b*) The method of correlation by the comparison of fossils; or, as it has been called, "matching," is the one that affords the best results. It includes the comparison of species, genera, families, and the general facies of a fauna. It is the basis of paleontologic correlation and geologic classification of the sedimentary rocks, with the exception of the stratigraphic and lithologic correlation of local formations.

(*c*) In nearly every section of strata there are considerable thicknesses of beds, in which, no fossils are to be found. These beds occur in nearly every formation. The record of life, during these nonfossiliferous periods of sedimentation, is broken.

(*d*) Many fossils have a great vertical range; and the occurrence of a few species of this character without the presence of species of known limited range can not be taken for the identification of any particular formation. If the laws of constancy and variation of the wide-ranging and long-enduring species are known, it may be possible to use them in the correlation of minor formations, and thus create an exception to the general rule.

(*e*) All paleontologic reasoning is based upon known data. By the discovery of a new grouping of fossils, or a different range of known species, the identification of horizons may be materially modified.

(*f*) In correlating a formation it is necessary to exercise caution before deciding that the contained fossils belong to any specified zone of the fauna characterizing a terrane or group of formations, and thus locating the exact stratigraphic horizon of the formation. A fauna may vary in its constituent parts and afford different groupings of species in localities not far distant.

(*g*) All correlations between widely separated provinces are based upon the general and not upon the specific character of the fauna; i. e., it is the general assemblage of a fauna in one basin that is compared with that in another basin.

Within limited areas the comparison of species and the grouping of species suffice to determine some particular horizon or formation. In widely separated parts of the same area or province there will

[1] Hall, James. On the Primordial fauna and Point Levi fossils. Am. Jour. Sci., 2d ser., vol. 31, 1861, p. 224.

be a greater difference in the species, and the general or the specific grouping of the genera will have to be taken as the data for comparison. In separate provinces the species may be the same in some instances; but it is by the comparison of representative species and genera that the correlations are to be made. In provinces separated by great distances, or upon two continents, the general assemblage of the characters of the two faunas are to be compared. It may be accepted as a general rule that the more detailed the comparisons are the more restricted is the area in which specific results are of value. The results, however, may be of the highest value in strengthening a correlation based upon representative types. The exception to this is the occurrence of similar life zones in widely separated regions.

(*h*) Zoologic provinces have been more or less limited in area from the beginning of Paleozoic time. This is shown by the character and distribution of the earlier Cambrian fauna. The provinces were as distinctly marked then as at any time during the deposition of the Paleozoic.

(*i*) Many of the earlier zoologists and paleontologists prior to the period of Darwin studied the strata and the contained fauna with the view that each group of species had a greater or less distribution and were then suddenly exterminated, a newly created fauna taking its place. This enabled them to correlate their formations with great accuracy, and to differentiate them upon the evidence offered by the occurence of a very few species.

(*j*) The environment or condition under which the faunas lived and were deposited is also to be noted. Whether they were littoral or pelagic, whether they lived in cold or warm water, upon a sandy or a muddy bottom, in salt or in fresh water, are all considerations which must be taken into account in discussing their value as factors in correlation.

(*k*) The presence of recurrent faunas in strata lithologically similar may give rise to imperfect and erroneous correlations. This is not liable to occur except in a limited geologic basin, where the conditions of sedimentation were uniform over large areas, and the environment of the fauna such that it continued, under favorable conditions, in some portions of the basin, and occupied other portions intermittently, as the varying phases of sedimentation were favorable or inimical to its distribution.

(*l*) The relative age, serial relation, or homotaxis of sedimentary formations is best determined by the marine faunas, as the conditions under which they lived and were deposited were much more uniform than those surrounding the terrestrial fauna and flora.

The evidence furnished by paleobotany is fragmentary, and its sequence is so interrupted by nondeposition and nonpreservation that no comparisons of great value have been established by its aid. What is true of paleobotany is also true, to a less extent, of terrestrial faunas.

It is only by accident and through peculiarly favorable conditions that land faunas have been preserved. With the marine faunas on the contrary the opportunities for the preservation of the fauna of each epoch were far greater, and the conditions of environment were more favorable for the uniform advancement and evolution of life over extended areas.

Life-zones.—The proof of the presence of life-zones in the geologic series is one of great importance in correlation. The subject has been so ably presented by Prof. H. A. Nicholson that I will quote it in full in preference to giving a synopsis of it or to presenting my own views, which accord essentially with those of the author. He says:

> While each geological rock-system is characterized by a general assemblage of distinctive types of animals and plants, the minor subdivisions of each system are likewise distinguished by the prevalence of particular forms of life. There are no doubt cases in which an extensive series of successive strata may appear to be characterized throughout by essentially the same organic types, there being apparently no restriction of special fossils to special horizons in the series. In so far as such cases have any real existence, they may be explained as instances in which a great series of sediments has been accumulated with such rapidity that there has been no time for marked biological changes, resulting in the dying out of old species and the introduction of new forms. In many cases, however, the apparent diffusion of the same kinds of fossils from the base to the summit of a series of beds perhaps two or three thousand feet in thickness is due simply to the fact that the organic remains met with in the formation have not been sufficiently investigated and that the exact horizon at which each occurs in the series has not been accurately determined. The determination of the horizons of particular life-forms is a work of time and demands both great stratigraphical knowledge and also a wide and accurate acquaintance with the characters of the fossils themselves, two requirements rarely fulfilled in the same individual.
>
> In a considerable number of cases, however, it has now been shown that the fossils of a given formation may be divided into two principal groups. In the one group is comprised a series of common forms of life, which may be regarded as characterizing the formation *as a whole*. In the other group are included certain special fossils confined to particular parts of the formation and characteristic of certain definite *horizons* or *zones*, within the limits of the formation. All the great formations are to some extent capable of being broken up into minor rock-groups, characterized by special life-forms. Some of the differences in the kinds of fossils found in different parts of the same formation must, of course, be simply set down to the fact that different kinds of sediment imply changed conditions in the sea, and hence changes in the marine fauna. If, for example, part of a formation consisted of limestone and part of sandstone, we should expect, beforehand, to find that each of these rock-groups would have some fossils not found in the other, since the two would have been formed under different conditions. Apart, however, from differences arising from causes of this nature, we meet with cases in which a formation, even if essentially homogeneous in its mineral nature, can be divided into *zones*, each of which is characterized by the possession of special groups of fossils. Organisms belonging to any class of animals may serve in this way as test forms ("Leit-Fossilien") for special horizons in a series of stratified formations, but there are particular groups of fossils which have been found to be preeminently available for this purpose. Among the older rocks of the earth's crust, the forms which have proved specially valuable for the determination of particular "zones" are the Graptolites, the Trilobites, and the Brachiopods, while the Cephalopods have been found to afford the most satisfactory tests in the case of the Secondary rocks. A well known instance of this subdivision of a system of strata by means of special types of fossils is that afforded by the Ordovician and Silurian

rocks of Europe, in which paleontologists, following Professor Lapworth, have recognized numerous well marked "life-zones," characterized for the most part by the possession of particular types of Graptolites, though, in some cases, the distinctive fossils belong to other groups Another well known example of the same phenomenon is afforded by the Jurassic deposits. These have been shown to contain a number of well marked zones, each of which is characterized by the possession of some special fossils, and particularly by some special Ammonite. These zones are extremely constant in any particular region, and they enable the observer to effect a division of the formation into special horizons, which have no stratigraphical existence and are not separated by any physical break, but are of the utmost paleontological importance and can be rendered readily available in working out the stratigraphy of any given area.

Certain life-zones appear to have nothing more than a local development and importance, but in other cases they have proved to be astonishingly constant even over very large areas. Perhaps the most remarkable known instance of the extension of particular life-forms over a vast area is that afforded by the Arenig rocks (a subdivision of the Ordovician system), which have been recognized as occurring in Europe, in Canada, and in Australia, and contain in all these widely remote areas the same peculiar types of Graptolites.

The principal difficulty that we have to confront in dealing with these "zones" is to produce any plausible explanation accounting for the destruction of the special life-forms of the one zone and the appearance of those of the next zone. For the most part, these zones are of very limited vertical extent, and they succeed each other in such a manner as totally to preclude the idea that the dying out of the old forms can have been in any way caused by a physical disturbance of the area. Perhaps the most probable view to adopt in the meanwhile is that the formations in which distinct and limited life-zones can be recognized were deposited with extreme slowness, whereas those which show an essentially compact and homogeneous fauna from base to summit were deposited with comparative rapidity. Upon this view, a formation like the Lias is one formed by a process of very slow and intermittent sedimentation, the life-zones being separated by intervals during which sedimentation must have been at a standstill, but which were long enough to allow more or less considerable biological changes, some forms dying out or becoming modified while other new ones came in. Upon this view, further, a formation like the Lias, though of comparatively small vertical extent, may represent as long a period of time as the whole of such a great formation as the Lower Carboniferous, which appears to have been formed under conditions of comparatively rapid sedimentation.[1]

Life-zones have been determined in the Middle Cambrian or Paradoxides terrane of Sweden, Wales, New Brunswick, and Newfoundland or the Atlantic Basin Province. In a broader range the genera Olenellus, Paradoxides, and Dikelocephalus are considered typical of the three primary zones or divisions of the Cambrian group. They are of unequal value and decrease in precision from the older to the later faunas. The genus Olenellus has a wide distribution in western Europe and North America, while Paradoxides is more limited in America, and the true Dikelocephalus probably has a still smaller geographic range.

Stage of evolution.—The evolution of organic life is a factor in correlation that has been assuming some importance within the last few years. To be of practical use the paleontologist must have a thorough,

[1] General Introduction, Manual of Paleontology, by H. A. Nicholson and R. Lydekker, vol. 1, 1889, pp. 58-60.

accurate knowledge of the species and their life history, including that of the genus and family to which they belong. Types of restricted range and short duration are of little importance, except as expressing the stage of development of their genus. The persistent, long-enduring types, that range from formation to formation and even from group to group, may be of service if their study and analysis have revealed characters by which their relative stratigraphic position, in a given area, may be determined. The evolution of genera is of greater value, and the analyses of the development of specific types within them may be used in the identification of horizons.

Extended to groups of genera, families, or orders, correlation by the known evolution of the faunas may be used in a general way. In the presence of other reliable data it is of relatively small value. Only in instances where there are no other data that can be made available will it be really of practical service to the geologist.

Even under the best conditions and circumstances great care must be used, owing to the varying conditions caused by environment and the unequal evolution of organisms in different geographic areas or basins. I do not wish to imply that this method of correlation should be entirely overlooked or dismissed in the presence of more reliable data. It can be used in connection with other methods in correlating any formation or group of formations, but only in extreme cases should it be considered the only factor. When used, the result obtained can be considered as little more than provisional.

Life history.—A careful study of the life history of the various elements of the faunas promises to yield data that may be important in correlation. An illustration of this is afforded by Prof. H. S. Williams's study of *Spirifera lævis*.[1] This is a type that is represented by various forms from the Niagara limestone of the Silurian to the summit of the Devonian, that are evidently descended one from the other, although they have been described under several specific names. At each horizon the variation from the initial form serves to locate its stratigraphic horizon and thus its relative age and position in space and time. The tracing of the migration of forms from one area to another and the changes produced upon them during this migration are to be taken into consideration. The theory of Prof. Alpheus Hyatt,[2] that there is a cycle of forms in the geologic series and a corresponding cycle of variation in the species of that series and in the individuals of any one species, may lead to practical results. He finds it to prevail very extensively in the Cephalopoda, and it will undoubtedly be found to apply to all the other zoologic groups. The conclusions obtained will be more or less marred by the imperfections of the geologic and life record, but I look forward to the time in the future when minute biologic studies

[1] The Life History of Spirifer lævis, Hall. Ann. N. Y. Acad. Sciences, vol. 2, 1881, pp. 140–160, pl. xiv.

[2] Genera of Fossil Cephalopoda. Proc. Boston Soc. Nat. Hist., vol. 22, 1883, pp. 253–265. Also, many other papers by Professor Hyatt, referring to and describing the Cephalopoda.

of the faunas, in connection with a careful study of the sedimentation and stratigraphy, will make our present methods appear to have been lacking in scientific precision.

Contemporaneity and Homotaxis.—When it was once established that a certain order of succession of fossils occurred in Europe, it was concluded that identical or similar assemblages of organisms would be found to prevail elsewhere over the earth; and that the geographic distribution of each successive fauna was world-wide, each fauna being a new creation. The present view is, that the chronologic succession of the fauna is local, as proved by the existence of zoologic provinces, and that each fauna is descendant from some preexisting fauna. This result is modified for each province by the migration of faunas and portions of faunas from province to province. Notwithstanding the various elements that influenced the evolution of the faunas, it is found that the general succession of species and faunas is in the aggregate the same all over the world, however much it may have been broken, advanced, or retarded in certain areas in ancient or relatively recent geologic time.

Prof. Huxley, when introducing the term "Homotaxis," said:

> Edward Forbes was in the habit of asserting that the similarity of the organic contents of distant formations was prima facie evidence, not of their similarity, but of their difference of age; and holding as he did the doctrine of single specific centers, the conclusion was as legitimate as any other; for the two districts must have been occupied by migration from one of the two, or from an intermediate spot, and the chances against exact coincidence of migration and of imbedding are infinite.
>
> In point of fact, however, whether the hypothesis of single or of multiple specific centers be adopted, similarity of organic contents can not possibly afford any proof of the synchrony of the deposits which contain them; on the contrary, it is demonstrably compatible with the lapse of the most prodigious intervals of time, and with interposition of vast changes in the organic and inorganic worlds, between the epochs in which such deposits were formed.[1] * * *
>
> There seems, then, no escape from the admission that neither physical geology nor paleontology possesses any method by which the absolute synchronism of two strata can be demonstrated. All that geology can prove is local order of succession. It is mathematically certain that, in any given vertical linear section of an undisturbed series of sedimentary deposits, the bed which lies lowest is the oldest. In any other vertical linear section of the same series, of course, corresponding beds will occur in a a similar order; but however great may be the probability, no man can say with absolute certainty that the beds in the two sections were synchronously deposited. For areas of moderate extent, it is doubtless true that no practical evil is likely to result from assuming the corresponding beds to be synchronous or strictly contemporaneous; and there are multitudes of accessory circumstances which may fully justify the assumption of such synchrony. But the moment the geologist has to deal with large areas or with completely separated deposits, then the mischief of confounding that "Homotaxis" or "similarity of arrangement," which *can* be demonstrated, with "synchrony" or "identity of date," for which there is not a shadow of proof, under the one common term of "contemporaneity" becomes incalculable, and proves the constant source of gratuitous speculations.[2]

[1] Quart. Jour. Geol. Soc., London, vol. 18, 1862, p. xlv.

[2] Op. cit., p. xlvi.

In this connection the student should read Mr. J. E. Marr's paper on Homotaxis.[1]

Percentage of species.—This method of paleontologic correlation was employed by Sir Charles Lyell. He found a certain percentage of species identical with living forms in one horizon, the Eocene; a larger percentage in the Miocene, and a still larger one in the Pliocene. He then concluded the Eocene represented the oldest and the Pliocene the latest deposit. He thus classified the formations and gave an indirect method for their correlation in different areas. It is not capable of application where all the members of a fauna are extinct.

III. LITHOLOGIC CHARACTER.

Lithologic character has very little value in establishing correlations, when comparing formations outside of limited areas. The constituents of a rock may differ in their chemical and mechanical condition in a stratum that is proved by other evidences to be continuous. In some instances lithologic characters may be of value, especially in areas where the stratigraphic sequence of the beds is known and paleontologic evidence is lacking. Dr. R. D. Irving used the method successfully among the pre-Cambrian rocks of the Lake Superior region, and says of it:

> Its value in tracing formations from point to point can hardly be overestimated, being as great as that of paleontological evidence and, in my judgment, of much the same nature. As we trace formations and their minor subdivisions from place to place we must of course constantly check lithological evidence by stratigraphy. As we pass from one extremity of the field to the other, changes in lithological characters of course come in, and these changes might lead to unsafe conclusions were we to compare stratal successions too distantly removed from one another; but when we work from point to point such changes are detected as they gradually appear, and are provided for.[2]

An illustration of the value of the method is shown by the correlations made by the brothers Roger's[3] in Virginia and Pennsylvania, where they correlated the quartzites, shales, and limestones by their lithologic characters along an extent of several hundred miles. When, however, they came to carry this correlation without that area of sedimentation, the inadequacy of the method is shown by the fact they correlated the Lower Cambrian quartzite with the Upper Cambrian quartzite about the Adirondacks of New York. A still more striking illustration of erroneous correlation by this method is that made by Prof. N. H. Winchell[4] in correlating, as members of one formation, the

[1] Proc. Cambridge Phil. Soc., vol. 6, 1887, pp. 74-82.

[2] Seventh Ann. Rep. U. S. Geol. Survey, 1885-'86, 1888, pp. 378, 379.

[3] A system of classification and nomenclature of the Paleozoic rocks of the United States, with an account of their distribution, more particularly in the Appalachian mountain chain. Am. Jour. Sci., vol. 47, 1844, p. 112.

[4] The crystalline rocks of Minnesota. General report of progress made in the study of their field relations. Statement of problems yet to be solved. Geol. and Nat. Hist. Survey of Minn., 17th Ann. Rep. for 1888, 1889, p. 49.

Lower Cambrian quartzite of the western slopes of the Green Mountains, the Upper Cambrian Potsdam sandstone of New York, the pre-Cambrian Sioux quartzites of Minnesota, the pre-Cambrian Baraboo quartzite of Wisconsin, and the pre-Cambrian quartzite of the Keweenawan series of Lake Superior.

Lithologic character is often of great value within limited areas and where the formation can be practically traced from place to place. As this can rarely be done, it is best to seek other data and to combine with the lithologic, the stratigraphic and paleontologic evidence, if it is possible to obtain any.

IV. UNCONFORMITY.

Of all the data of correlation that of unconformity of the formation correlated, with its superjacent or subjacent formation, would appear at first sight to be the most unreliable. In most instances it is, but where combined with other data it has a certain value. We find it used in the earliest correlations made of the Potsdam sandstone of New York, with the basal sandstone all along the Appalachian Range south through New Jersey, Pennsylvania, Maryland, Virginia, Tennessee, Georgia, and Alabama. It is also used in the correlations made between the Potsdam sandstone of New York and the sandstone of the south shore of Lake Superior, and the fossiliferous sandstones of Wisconsin, Iowa, and Minnesota, that were correlated with the Potsdam sandstone by Messrs. Owen, Hall, and later observers. In fact, it is implied in nearly all the references of strata to the Potsdam horizon in other localties than that of the typical area about the Adirondack Mountains of New York. It was not, however, until the appearance of Prof. R. D. Irving's essay on the classification of the earlier Cambrian and pre-Cambrian formations[1] that full significance was given to the value of unconformities in correlation.

The problem is presented by Dr. Irving as follows:

> (1) To determine upon the grander divisions (groups) to be made in classifying the rocks independently of their relations to the general geological column; (2) to extend these divisions to other portions of the same geological basins; and (3) to correlate these divisions with those of different and distant geological regions. This is the problem which presents itself in the Lake Superior region, at the base of the Grand Cañon of the Colorado, in central Texas, Newfoundland, and in other portions of North America.
>
> In any attempt to solve such a problem we can make use of one or more of three kinds of characteristics in the formations involved, viz: (1) their paleontological characteristics, (2) their lithological characteristics, and (3) their mutual structural relations.[2]

Under the third title, "their mutual structural relations," he considers unconformity as a basis for classification[3] discussing the general nature and significance of conformities and the distinguishing characters of true unconformities. A description is given of the Potsdam-

[1] Seventh Ann. Rep. U. S. Geol. Surv., 1885–'86, 1888.
[2] Op. cit., p. 371. [3] Op. cit., p. 390.

Huronian unconformity on the north shore of Lake Huron, the Potsdam-Keweenaw unconformity, the Laurentian-Huronian unconformity and others of the Lake Superior region. This is followed by a section on the use of unconformities in classification.[1] In this the use of unconformities in defining the grander groups of strata and in correlating the formations of a single geologic basin are discussed. Under the first, he says:

> Returning to our problem as originally stated, we have next to consider how far unconformaties may be made use of in defining the grander groups of strata in a region in which the succession of these strata has been determined. Further argument than that already given in discussing the nature and kinds of unconformity is hardly necessary to show that genuine unconformities, indicative of great lapses of time between the periods in which the strata on either side of the break in each case were respectively made, are of prime value and importance in determining the limits of the grander groups of the geological formations, whatever use we may make of paleontological and lithological characters in determining subordinate divisions. Such structures as the greater ones of the true unconformities, above considered, indicate lapses of time great enough to cover extended periods of mountain-making, always a slow process, and also great periods of denudation or exposure to the atmospheric agencies. It is hardly possible for us to compare such time gaps with the time necessary for the formation of definite thicknesses of strata, but the thicknesses of strata corresponding to such breaks must surely always be very great.
>
> If we take for instance the gap indicated by the relations of the Potsdam sandstone to the ancient gneissic formation of the northwest, as above illustrated by a number of examples, we find that it was long enough to cover not merely one period of rock alteration, orographic movement, and land surface exposure, but three such periods, between which were times long enough for the accumulation of thicknesses of strata aggregating over 60,000 feet, a thickness exceeding that of the entire Paleozoic series in its greatest development in the Appalachian region. It is true that a portion of this 60,000 feet is made up of volcanic materials, chiefly lava flows. The accumulation of such materials may, it is true, have been more rapid than is the case with ordinary fragmental deposits; but the accumulation of such a mass of eruptive material must have occupied at least a considerable lapse of time; while more than one-half of the 60,000 feet, or an amount approximating the maximum Paleozoic accumulations in the Appalachian region, is made up of genuine detrital deposits. When we consider that in addition to the time necessary for the accumulation of this mass of sediment there intervened between the Potsdam and the gneisses three periods of rock alteration, mountain-making, and complete mountain removal, it becomes plain that the time gap indicated by this unconformity must have exceeded the entire Paleozoic era. More probably, indeed, it equalled all later geological time. Each one of the three unconformities mentioned must of course have required a shorter period than this greater gap, but in each case the relations of the several formations are such as to indicate periods of time only comparable to the periods necessary for the accumulation of one of the great geological groups.[2]

The use of unconformities in correlating the formations of a single geologic basin, where the exposures of the formations are not continuous, is illustrated by a tabulation showing the general succession of formations in various districts from the northern end of Lake Huron to Dakota and from central Wisconsin to the north shore of Lake Superior. This table shows that in various localities there is a great unconformity

[1] Op. cit., p. 438.

[2] Op. cit., pp. 438, 439.

between the Laurentian and the Huronian, between the Huronian and the Keweenawan, where the two series of rocks are present, and between the Keweenawan and the Cambrian if these two occur in the same area.

He next takes up the use of unconformities in establishing general relations. Under this heading we quote as follows:

Having established the general order of succession and the grander groups of the strata for a given geological province, the question which arises next in order is how to correlate these divisions with those of other geological provinces, and more particularly with the established divisions of the general geological column.

It will take but little consideration of the causes which have been at work in the production of such unconformities as have been above cited to make us realize that such breaks as these must be widespread in their influence. Great unconformities, in which the strata below the unconformity have been subjected to folding, mark periods of orographic movements which will, in general, have been extensive somewhat in proportion to the intensity of the folding process.[1]

It is well known, indeed, that some of the greater physical breaks in the strata of one continent may have their parallels among the strata of another continent. The interruption between the Paleozoic and the Mesozoic is intercontinental, if not world wide. Equally extensive is the great break between the Mesozoic and the Cenozoic. Each of these physical breaks corresponds to an immense change in life conditions. But, if we may judge from structural relations, from the amount of intervening denudation, and from the rank already attained by the life of the lowest of the fossiliferous Cambrian formations, neither of these great breaks corresponds in length of time interval to the break between the lowest of the distinctly fossiliferous formations and the youngest of those beneath it.[2]

The great structural breaks furnish, at times at least, a more trustworthy guide. If, for instance, we make a comparison of the succession of Cambrian and pre-Cambrian strata in the Lake Superior region with the succession revealed in the depths of the Grand Cañon of the Colorado, we find some singular correspondences between the structural breaks of the two successions. In each one of these regions the Potsdam sandstone is strongly characterized by its well known fauna. In each region the sandstone traverses the edges of a gently bowed but deeply denuded formation composed of a great thickness of detrital and eruptive materials. Below these formations in each region, and separated from them in each case by one of the strongest of unconformities, is a great quartzitic series, while below this series again in the Lake Superior region, and separated from it by still another of the most notable of unconformities, is the great Laurentian gneissic series. That this series also exists in the base of the Grand Cañon we have good reason to believe.

Such a striking similarity in succession as this certainly most strongly suggests the conclusions that the physical breaks of the two regions were coincident in point of time (that is, that the mountain-making movement which preceded the deposition of the Potsdam sandstone of the Lake Superior country corresponded with that which preceded the Tonto sandstone of the Grand Cañon region); that the mountain-making periods preceding the deposition of the Grand Cañon series of the Grand Cañon district and of the Keweenaw series of the Lake Superior region were equally synchronous; and, finally, that the Grand Cañon series is, in general, the equivalent of the Keweenaw series, while the pre-Grand Cañon rocks are the equivalent of the Lake Superior Huronian.

Of course such correlations as these should be made, for the present at least, somewhat provisionally; but, on the other hand, they must be taken as of much greater value than correlations between distant formations established on feeble fossil evidence.[3]

[1] Op. cit., p. 443. [2] Op. cit., p. 444. [3] Op. cit., p. 445.

The question is asked, is the term Cambrian to stop at the first unconformity below the Potsdam sandstone? Is it to extend to the second of those uncomformities, or to the third? Or is it to include, finally, the lowest of the formations of the region?

He makes the following reply to these questions:

All these usages of the term have been made. In taxonomical value the term Cambrian is designed, of course, to correspond to the terms Upper Silurian, Lower Silurian, Devonian, Carboniferous, etc., which terms are based primarily upon the general continuity for each one of the periods to which they correspond of similar life conditions. In no case, however, has one of these terms been allowed to span any such unconformable break as the least of those beneath the Potsdam sandstone of the Lake Superior region. Minor breaks in the succession have been included within a single one of these geological groups because—although in every case of a physical break, even the smallest, a corresponding break in life-succession is found—there have been found on both sides of the break fully developed faunas of general similarity in characters; but no great break in the succession such as those with which we are now concerned has ever yet been found to be spanned by a continuity of forms. The conclusion, therefore, seems inevitable that we should not extend the term Cambrian over any such break, at least until there shall have been found closely corresponding faunas on opposite sides of the interval. Were such faunas to be discovered the greatness of the unrecorded interval would still remain, and we should have indicated only a singularly long continuance of similar life-conditions. Even then the question might arise as to whether continuity of life-conditions should outweigh the great lapse of time indicated by the physical hiatus.[1]

Finally Dr. Irving states that

The structural breaks called unconformities are properly used in classification—

(1) *To mark the boundaries of the rock groups of a given region.*

(2) *To aid in establishing correlations between the formations of different parts of a single geological basin.*

(3) *To aid in the establishment of correlations between the groups of regions distantly removed from one another; but* caution is needed in attempting such correlations in proportion as the distances between the regions compared grow greater.

They are improperly ignored:

(1) *When the evidence they offer as to separateness is allowed to be overborne by anything but* the most complete and weighty of paleontological evidence.[2]

V. MISCELLANEOUS.

Homogeny.—A method of correlation that has frequently been used has recently been named by Mr. W J McGee "Homogeny" or correlation by community of genesis.[3] Mr. McGee defines it as follows:

The method of correlation devised to systematize the structure of the Coastal Plain combines the desirable features of the older methods, and adds thereto the interpretation of the products of the several physical processes operating upon the earth's exterior.[4]

The older methods mentioned are those of stratigraphic continuity, lithologic correlation or correlation by petrography, and paleontologic

[1] Op. cit., p. 416.
[2] Op. cit., p. 448.
[3] Am. Jour. Sci., 3d ser., vol. 40, 1890, pp. 36–41.
[4] Op. cit., p. 36.

correlation. He considers that "the method involves a yet broader conspectus of phenomena and principles than the paleontologic method; for in its application it is necessary mentally to restore the various physical and biotic conditions of the past, just as paleontology vivifies the fossils of past ages." Again:[4]

> In discriminating the general and local genetic conditions it is necessary to ascertain the relations between each formation and its newer and older neighbors, and to interpret the record of each unconformity in terms of continent growth. By this means the different parts of a formation may be found to represent not only general community of genesis but community of beginning and ending; in short, entire community of structural relation. Each part of the formation then records in similar terms the same episode in continent building and world growth.
>
> So, when a coastal plain formation is found to represent general community of genesis and structural relation in its various parts it is considered homogenic, and accepted as a record of an episode in geologic history. The parts may or may not be homotaxial; one part may be slightly older than another part; but in a general way it is contemporaneous throughout. Homogeny implies not only equivalence but synchrony.

The principles of homogenic correlation have long been used in the correlations of formations by geologists. An illustration of this is the correlations that have been made of the Potsdam sandstones of New York with those of the Mississippi Valley, the eastern slope of the Rocky Mountains, the islands of Texas and Missouri, and the valley of the St. Lawrence. In these correlations to subjacent and superjacent formations, stratigraphic continuity, lithologic or petrographic resemblance, and similarity of organic remains have all been used.

Under the definition of homogeny, that is, correlation by community of genesis, decided errors must necessarily occur unless checked by paleontologic data. An illustration of this is the correlation of the Potsdam sandstone of the Adirondack Mountains of New York with the "Granular Quartz" of western New England and southeastern Pennsylvania, and the Chilhowee sandstone of Tennessee. These sandstones are lithologically alike, they were accumulated along a coast line, their petrographic characters are the same, and the action of the waves upon and the distribution by tidal currents of the sediments originating from similar crystalline rocks all point to a community of origin; in fact, they did originate in the same manner. They have been correlated upon the characters mentioned for upwards of 40 years, but the study of the fossil remains shows they are not equivalent or synchronous. One represents the basal beds of the Cambrian system and the other the Potsdam sandstone or the closing deposits of Cambrian time in the same area. I think that after we have fully proven to our satisfaction the similarity of origin or the community of genesis we must still rely upon paleontologic data for the final determination of geologic equivalence. For the determination of synchrony, except in a limited area, there is little hope for satisfactory conclusions by any method yet devised.

[4] Op. cit., pp. 38, 39.

Topographic features in correlation.—Topographic features may ind cate relative geologic age in the discussion of the later formations; bu in dealing with the Lower Paleozoic it has thus far been found to b impossible to obtain the evidence of newer or older topographic featur that are of value. Mr. G. K. Gilbert has used it successfully in discus ing the age of the Equus fauna of Lakes Mono and Lahonton of Cal fornia and Nevada.[1]

[1] U. S. Geol. Survey, Monograph, vol. 1, 1890, pp. 393–402.

INDEX.

A.

Page.

Acadian series, J. W. Dawson on 62
definition of 248
Georgia 303
formations correlated with 360
Acadian slates of Alabama 305–306
Adams, C. B., on quarts rock of Vermont. 95
on red sandrock 97, 250–251
on Taconic slate 99
fossils of red sandrock 150
Adirondack subprovince, paleontology of 229–232
Cambrian rocks of 341–347
sediments of 347
problems for investigation in 381
Agassiz, A., on Lake Superior sandstone. 195
Agassiz, L., on rocks of Braintree, Massachusetts 74
on correlation by fossils 419–420
Ami and Sowter, fossils from Quebec 232
Alabama, M. Toumey, on rocks of 146
E. A. Smith, on rocks of 146–148
Cambrian rocks of 146–148, 305–308
Antelope Spring, Utah, section 320
compared with other sections 320
Anse au Loup, l', Newfoundland, section. 253–254
Appalachian province, definition of 91–274
Cambrian rocks of 91–148, 274–312
Archæocyathus, remarks on 319
Argentine Republic, Cambrian rocks of. 379
Arizona, Cambrian rocks of 219–221, 356, 357
J. S. Newberry on rocks of 219–220
J. W. Powell, on rocks of 220–221
G. K. Gilbert, on rocks of 220
A. R. Marvine, on rocks of 220–221
C. A. White, on fossils of 221
C. D. Walcott, on rocks of 221
paleontology of 235
problems for investigation in 385
Atlantic Coast province, definition of 50, 253
Cambrian rocks of 50–78
paleontology of 78–90
summary of knowledge of Cambrian rocks of 253–274
sediments of 358
fauna of 370
physical characters of strata 273–274
Atlantic Coast and Rocky Mountain province 386–387
Atlantic Coast series, J. W. Dawson on .. 56
Atlantic Coast series of America and Wales 373, 374–375

Page.

Attleborough, Massachusetts, E. Hitchcock on limestone in 73
T. S. Hunt on rocks at 73
Auroral limestone, T. S. Hunt on 127–128
Au Sable Chasm, New York, section 343–344
Australia, Cambrian rocks of 378–379
Avalon and Fortune Bay, Newfoundland, section 257–258

B.

Bailey, L. W., on rocks of New Brunswick 61, 64
Bakewell, R., on use of fossils in correlation 397–398
Balcony Falls, Virginia, rocks of 136
section at 293–294, 297, 298
Bannock Range, Idaho, section 322
Bar Harbor, Maine, rocks at 66
Barrande, J., on fossils from Braintree, Massachusetts 75, 88
on fossils from Georgia slate 99
primordial fauna of Texas 234
definition of primordial 243
use of fossils in correlation 416–417
Bayfield, H. W., on rocks of Straits of Belle Isle 50
on Lake Superior sandstone 188, 252
Beecher & Hall, on Mohawk Valley 207
Belle Isle shale 50, 51
Belle Isle Straits, rocks of 102, 104
Bell, Robert, on rocks of Hudson Bay 122
Bennington, Vermont, section 276
Big Cottonwood Cañon, Utah, section 157–158, 159–160
Big Horn Mountain range, Montana, section 325–326
Bigsby, J. J., on rocks near Quebec 114
on Montmorenci Falls 116
on rocks of the St. Lawrence 116
on Lake Superior sandstone 188, 252
on Potsdam, of New York 206
correlations of 395–396
comparison of rocks of New York and Wales 418–419
Billings, E., on red sandrock 97
on Georgia slate 102
on Winooski marble 103–104
on Point Levis fossils 116–117, 150, 151
on correlation of faunas 150
on fossils from Potsdam group of Vermont 150

Page.

Billings, E.—Continued.
on fossils from red sandrock 150
on fossils in correlation 406–407
Black Hills, Dakota, E. James on rocks of 214
H. Engelmann on rocks of 214
Meek & Hayden, on rocks of 215
F. V. Hayden, on rocks of 215–216
N. H. Winchell, on rocks of 216
R. P. Whitfield, on fossils of 216
H. Newton, on rocks of 216
F. R. Carpenter on 216
fossils of 233, 234, 348
rocks of 347–349
Bohemia, Cambrian rocks of 275
Bonne Bay, Newfoundland, section 51, 255–256
fossils from 256
Boston and vicinity, J. W. Webster on rocks of 72
E. Hitchcock, on rocks of 73–75
Bow River series 164, 326–327
Bradley F. H., on rocks of North Carolina 138–139
classification of 143–144
on rocks of Utah 156, 157
on rocks of Idaho 161
on rocks of Wyoming 212
on fossils from the Adirondacks 231
correlations by 411–412
Braintree, Massachusetts, L. Agassiz on rocks at 74
W. B. Rogers, on rocks at 73, 74
I. Lea, on rocks at 74
C. T. Jackson, on rocks at 74
J. Barrande, on fossils from 75, 88–89
N. S. Shaler, on rocks at 75
T. S. Hunt, on rocks at 75–76
W. W. Dodge, on rocks at, cited 75
W. O. Crosby, on rocks at 76, 77–78
J. Green, on fossils from 88
W. B. Rogers, on fossils from 88
C. T. Jackson, on fossils from 89
A. Ordway, on fossils from 89
W. W. Dodge, on fossils from 89
R. P. Whitfield, on fossils from 89
C. D. Walcott, on fossils from 89
Braintree quarry, Massachusetts, M. E. Wadsworth, on 271
Bretonian, definition of 247
Brigus, Newfoundland, fossils of 55
Brigus Head, Newfoundland, section 260
British Columbia, G. M. Dawson on rocks of 163, 164, 165
R. G. McConnell on rocks of 164
Broadhead, G. C., on rocks of Missouri ...200–201, 340–341
Brögger, W. C., on Prospect Mountain fauna 314
Brooks and Pumpelly, on Lake Superior sandstone 196
Buckley, S. B., on rocks of Texas 218
Burnet County, Texas, section 354–355

C.

Calciferous sandrock in Wisconsin 172, 177
Calvin, S., on well at Washington, Iowa .. 188

Page.

Cambrian continent 364–365, 386
Cambrian faunas, order of succession of, in America 361
Cambrian, base of 362
sedimentation of 362–363, 363–369
summit of 362–363
faunas of 369
subdivision of 370–373
sediments of 385–386
limits of 383–389
Cambrian time, geographic areas in 49, 368–369
Cambrian group, delimitation of 17
divisions of 49, 389–390
A. R. C. Selwyn on 119
definition of, by Sedgwick and Murchison 227–229
divisions of, by A. Sedgwick 239
use of in America 241
where separated from Silurian 241, 363
sediments of in eastern Massachusetts 272
synopsis of 369
formations of 359–369
Cambrian and Taconic, T. S. Hunt on 106
use of 368
Cambric, used by P. Frazer 121
Camp Baker, Little Belt Mountains (Montana) section 225
Campbell, J., Nova Scotia gold field 57
Campbell, H. D., on rocks in Virginia 127
Campbell, J. L., on rocks of Virginia 125, 126
Campbell, J. L. and H. D., on rocks of Virginia 126
Canada, geologic map of 50, 119–129
W. E. Logan, on rocks of 207–208
Alexander Murray, on rocks of 208
problems for investigation in 332
Canada Bay, Newfoundland, section .. 257, 273
Canadian extension of the northern Appalachian district, Cambrian rocks of 114–123, 285–287
Canadian extension of Adirondack subprovince, Cambrian rocks of 207–208
Canadian extension of Rocky Mountain province, Cambrian rocks of 326–327
Canadian extension of upper Mississippi province, Cambrian rocks of 334
Cape Breton, G. F. Matthew, on rocks of. 55
H. Fletcher on rocks of 63, 266–267
G. F. Matthew, on fauna of 65, 84
Caradoc sandstone, position of 239
Carpenter, F. R., on Black Hills 216, 348–349
Castle Mountain group 164, 326, 327
Chamberlin, T. C., on Potsdam sandstone of Wisconsin 179
work of, in Wisconsin 179, 180
on Lake Superior sandstone 198, 338, 339
on fossils from Wisconsin 226, 227–228
Chapman, E. J., on Climactichnites 231
Chateaugay Chasm, New York, section ... 342–343
Cherokee slates described 136
Chester, F. D., on Potsdam of Delaware .. 123
Chikis quartzite, P. Frazer on 129
description of 268, 289
Chilhowee, definition of 251

Page.

Chilhowee sandstone, J. M. Safford on... 300-301
China, Cambrian rocks of..... 377-378
Cambrian fauna of..... 377-378
Chocolocco..... 247
Clarksburg Mountain, Massachusetts, section..... 275-276
Classification, geologic..... 17
Clemson, T. G., sections in Virginia..... 133
Colorado, Cambrian rocks of.... 209-210, 351-354
F. V. Hayden on rocks of..... 209
A. C. Peale on rocks of..... 209-210
Arnold Hague on rocks of..... 210
S. F. Emmons on rocks of..... 210
fossils from Quandary Creek, in..... 210, 234
synopsis of Potsdam rocks of..... 353
problems for investigations in..... 384
Colorado River section..... 220
Comstock, T. B., on rocks of Wyoming... 212-213
division of Cambrian of Texas ... 219, 355-356
definition of Katemcy..... 246
of Riley..... 246
of Hickory..... 246
on rocks of Wind Mountains..... 349
Connasauga, definition of..... 246
Conrad, T. A., formations of New York.....203, 204, 205
on fossils of Adirondacks..... 229
on use of fossils in correlations..... 399-401
Cook, G. H., on Potsdam in New Jersey.. 122-123
on Green Pond Mountain rocks..... 123
Coosa, definition of..... 247
Coosa shales, fossils from..... 305
E. A. Smith on..... 308
Coosa Valley, Alabama, rocks of..... 308
Cornwall iron mines, T. S. Hunt on..... 127
Correlation of North American and British strata..... 417-418
Correlation, methods of..... 421-434
superposition in..... 421-422
use of organic remains in..... 422-428
life zones in..... 424-425
stage of evolution in..... 425-426
life history in..... 426-427
contemporaneity and homotaxis in... 427
percentage of species in..... 428
lithologic character in..... 428-429
unconformity in..... 429-432
homogeny in..... 432-433
topographic features in..... 434
Crosby, W. O., on rocks at Frenchman's Bay, Maine..... 68-69
on rocks at Braintree, Massachusetts. 76, 77-78
on Cambrian rocks of eastern Massachusetts..... 268-270
on rocks of Nahant..... 271

D.

Dakota, Cambrian rocks of..... 214-216, 347-349
Dale, T. Nelson, work of, in Vermont..... 283
Dames, W., on fauna of Cambrian of China..... 377
Dana, J. D., on granular quartz of Massachusetts..... 106-107
on red sandrock..... 107

Page.

Dana, J. D.—Continued.
on A. Wing's discoveries in Vermont 107
quartzites of eastern New York..... 109
principles of correlations..... 407-408
Dana, J. F. and S. L., on rocks of eastern Massachusetts..... 72
Dana and Grinnell on rocks of Little Belt Mountains, Montana..... 162
Daniels, Edward, fossils from Black River, Wisconsin..... 223
Dawson, G. M., classification of the Cambrian in Canada..... 67, 123
on rocks of British Columbia.....163-164, 165
on Selkirk range, British Columbia... 165
Dawson, J. W., on Atlantic coast series.. 56, 59
Nova Scotia metamorphic slate..... 57
on rocks of New Brunswick..... 60
on strata at St. John, New Brunswick 61
on Acadian series..... 62
on fossil tracks from Canada..... 231
on Cambrian..... 241
definition of Acadian..... 248
Delaware, F. D. Chester on Potsdam of... 123, 288
De la Beche, on use of organic remains... 398
Devine, T., trilobites of Point Levi..... 151
Dewey, Chester, work of, in Massachusetts..... 93-98
Diamond Creek, Arizona, section..... 219
Dikellocephalon..... 222
Dodge, W. W., on fossils from Braintree. 89
on rocks at Braintree, cited..... 75
Dutchess County, New York, Mather, Smock, and Dwight on rocks of.. 111-112
granular quartz in..... 276
rocks of..... 283-284
Dutton, C. A., on Tonto of Arizona..... 221
Dwight, W. B., on the rocks of Dutchess County, New York..... 111
fossils from Poughkeepsie, New York 153
on rocks of New York..... 283-284

E.

Eastern border or Adirondack sub-province, definition of..... 201
Cambrian rocks of..... 201-208
Eastern sandstone, description of.....197, 335-336
definition of..... 253
Eaton, Amos, nomenclature of..... 92-93
on rocks of Vermont..... 98
definition of granular quartz..... 260
correlations of.....392-395, 399
on use of organic remains..... 394
East Rutland, Vermont, limestones of... 276
Elliott, J. B., on rocks of Tennessee..... 144
Ells, R. W., on Cambrian rocks of province of Quebec..... 120 121
on rocks near Quebec..... 285-286
Emmetsburg, Iowa, section..... 187
Emmons, E., classification of..... 94, 403
on granular quartz..... 94-95
on Red Sandrock..... 96
on Taconic system..... 98
on Montmorenci Falls..... 114
fossils of Taconic system..... 148-149
on Potsdam sandstone....202-203, 204, 205, 206

Page.

Emmons, E.—Continued.
on fossils of Adirondacks 229, 231
on Cambrian in America 240
definition of Taconic 242–243
definition of Potsdam 244
Emmons, S. F., Big Cottonwood Cañon section 157–158
tabulation of rocks of Colorado 210
on rocks of Colorado 351–352
Endlich, F. M., on rocks of Wyoming 213
Engelmann, H., on rocks of Black Hills 214
English and American classifications compared 376
Estoria, Cambrian rocks of 375
Etheridge, R., on Cambrian of Australia 378–379
Eureka District, Nevada, fossils from 167–169
section 313

F.

Fall River, Massachusetts, W. B. Rogers, on rocks at 75
Ferrier, W. F., on fossil track from Adirondacks 232
Fitch, Asa, on Taconic slate and sandstone 98–99
on fossils of New York 148, 149–150
Fletcher, H., on rocks of Cape Breton 63, 266–267
Foerste, A. F., on rocks of Nahant, Massachusetts 78
on fossils from Nahant, Massachusetts 90
on rocks of eastern Massachusetts 271
Fontaine, W. M., on rocks of Virginia 135–137, 291–292–297
Ford, S. W., on rocks at Troy, New York 106
fossils from Troy, New York 152
Foster and Whitney, on Lake Superior sandstone 191–192, 193
table of rocks 192
France, Cambrian rocks of 375
Frazer, P., on South Mountain rocks 128
on Chikis quartzite 129
primal quartzites 129
on Hellam quartzite or Potsdam sandstone 131
on rocks of Pennsylvania 289
Frenchman's Bay, Maine, W. O. Crosby on rocks of 68–60

G.

Gallatin City, Montana, section 162
Gallatin River, Montana, section 162–163, 324
fauna of 325
Gaspé peninsula, A. P. Low on rocks of 120
Geiger and Keith on rocks at Harper's Ferry 137, 138, 291–292
Geikie, A., on Cambrian rocks of Scotland 376
on Cambrian rocks of Ireland 377
Geographic areas in Cambrian time 49, 368–369
Geologic classification 17
Geologic nomenclature, general considerations on 236–237
Georgia, G. White on rocks of 144, 145

Page.

Georgia—Continued.
Cambrian rocks of 144–146, 302–305
G. Little on rocks of 145
J. T. Henderson on rocks of 145
A. R. McCutchen on rocks in 145–146
paleontology of 155
Georgia and Alabama, problems for investigation in 302–304
Georgia, Vermont, C. D. Walcott on the Cambrian of 110
section at 277, 278, 279, 280, 281
Georgia formation, definition of 249, 250
J. Barrande on fossils of 99
Georgia group, C. H. Hitchcock on 101
Georgian, formations correlated with 309
Georgia slates, description of 98–113
E. Billings on 102
J. Marcou on 103
C. H. Hitchcock on 106
character of 278
Gesner, A., on rocks of New Brunswick 59
on rocks of Nova Scotia 56
Gilbert, G. K., work of in Nevada 156
on rocks of Arizona 220
definition of Tonto 245
correlations by 412
on topographic features in correlation 434
Grand Cañon, Arizona, section 562
Granular quartz, description of 91–96
E. Emmons on 94, 95
J. Hall on 100
C. H. Hitchcock on 106
J. D. Dana on 106, 107
C. D. Walcott on 112
N. H. Winchell on 106, 107
definition of 250
age of 250
distribution of 275, 276, 372
characters of 275–277
Great Bell Isle, Newfoundland, fossils of 153, 259, 261
section 258, 259
Green, Jacob, on Paradoxides 88
Green Pond Mountain rocks, G. H. Cook on 123

H.

Hague, Arnold, on rocks of Nevada 158, 159, 160
on rocks of Colorado 210
on the age of rocks of Laramie Hill, Wyoming 212, 350
definition of Hamburg 246
definition of Secret Cañon 246
definition of Prospect 252
Hall, C. E., on hydromica slates 129
on Potsdam of New York 207
Hall, James, on fossils near Troy 90
on granular quartz 100
on fossils of Vermont 100, 102
on fossils of New York 149
on fossils from red sandrock 149
on fossils of Hudson River group 149
on fossils of Quebec group 149

Page.

Hall, James—Continued.
Olenellus proposed by 491
on rocks of Wisconsin 173, 175–178
on age of sandstone of Wisconsin and Lake Superior 178
on Potsdam of Iowa 187
on Potsdam sandstone of New York 205
on fossils of Wisconsin....222, 223, 224, 225, 226
fossils of Adirondacks 229, 232
on names of formations 401
on use of fossils in correlation 401–403
methods of correlation 408, 409
principles of correlation 415, 416
North America and European formations compared by 416
Hall and Whitfield on fossils of Nevada 159, 166, 167
on fossils from Adirondacks 231
Hamburg, definition of 246
Hamburg limestone and shale, description of 315–317
fauna of 316, 317
Harper's Ferry, Virginia, Geiger and Keith on rocks of 137, 138
section 291, 292
Hartt, C. F., on St. John group 62
Hayden, F. V., on rocks of Montana 162
on rocks of Colorado 209
on rocks of Wyoming 211, 212
on rocks of Black Hills 215, 216
Hayes, C. W., definition of Connesauga 246
definition of Rome sandstone 247
definition of Weisner 251
section in Georgia 304, 305
Hellam quartzite 131
Hemmingford, Canada, section 343
Henderson, J T. on rocks of Georgia.... 145, 303
Hickory, definition of 246
Hicks, H., on Tremadoc group 242
on sediments of the Cambrian 373
on Cambrian of America and Wales. 375
Highgate Springs, Vermont, section ... 279
Highland range, Nevada, fossils from 171
section 317, 318
fauna of 318, 319
Hind, H. Y on Waverly gold district.... 57
on gold-bearing rocks of Nova Scotia. 58
on gneissoid series of Nova Scotia ... 58
Hitchcock, C. H. on Mount Desert, Maine 68
on rocks about Portland, Maine..... 68
on rocks of Maine. 69
classification of rocks in New Hampshire 70, 71
on classification of rocks in New England 72
on Georgia group 101, 249, 250
on the name Georgia 106
on rocks of Waterville, Maine..... 101
on quartz rock of Vermont..... 96
on fossils from Vermont 99
on formations of Vermont..... 104
on Potsdam in Vermont..... 105
on Winooski marble 105
on granular quartz..... 106

Page.

Hitchcock, C. H.—Continued.
on red sandrock 106
on Cambrian of Vermont..... 107
on sections in Vermont and New Hampshire..... 108
fossils of Potsdam group..... 223
proposes Potsdamic..... 252
on mica-schist series of New Hampshire 268
Hitchcock, E., on rocks at Attleborough, Massachusetts 73
on rocks of Boston and vicinity..... 73, 75
Housatonic River, rocks of 141
Homogeny, W J. McGee on 432, 433
Homotaxis, T. H. Huxley on..... 427
Hough, F. B., on Potsdam of New York .. 205, 206
Houghton, Douglass, on Lake Superior sandstone. 188–190
table of rocks of Michigan 189
Howell, E. E., on rocks of Nevada 156
Howley, J., on rocks of Newfoundland ... 53
Hudson's Bay, Cambrian rocks on ... 121, 122
Hunt, T. S., on rocks at Attleborough, Massachusetts 73
on rocks at Braintree, Massachusetts. 75–76
on geology of Vermont..... 104
on Cambrian and Taconic..... 108
classification in Canada 120
on Cornwall iron mines, Pennsylvania 127
on Auroral limestone 127, 128
correlations of 132, 414
on Potsdam of Pennsylvania..... 132
on Scolithus linearis 132
on Lake Superior sandstone 195, 197, 198
on Potsdam of New York 206
on Cambrian, cited 240
on Taconian 243
Huxley, T H., on homotaxis..... 427
Hyatt, A., on fossils of Straits of Belle Isle 54
on life history in correlation 426
Hydromica slates, C. E. Hall on 129

I.

Idaho, O. St. John on rocks of..... 161
F. H. Bradley on rocks of..... 161
A. C. Peale on rocks of 161
Cambrian rocks of.....161, 162, 320–323
Lower Paleozoic section 323
sedimentation of 328, 329
India, Cambrian rocks of..... 378
d'Invilliers, on Potsdam sandstone of Pennsylvania 130
on correlation of the Potsdam..... 404
Interior Continental Province, definition of 171, 330
Cambrian rocks of 171–221, 330–347
sediments of 358
fauna of..... 371
Iowa, Cambrian rocks of 187–188
Ireland, Cambrian rocks of..... 377
Irving, R. D., on rocks of Wisconsin..... 178–179
on Cambrian and pre Cambrian formations cited 181

Page.

Irving, R. D.—Continued.
on Lake Superior sandstone.....196–197, 198, 199, 335–336
definition of Madison..... 245
of Mendota..... 245
of Eastern and Western sandstone..... 252
on lithologic character in correlation. 428
on unconformities in correlation 429–432
Irving and Chamberlin on Lake Superior sandstone..... 199

J.

Jackson, C. T., on trilobite from Newfoundland..... 50
on rocks of New Hampshire..... 70
on rocks at Braintree, Massachusetts. 74
on fossils from Braintree, Massachusetts..... 89
on red sandrock..... 96
on Lake Superior sandstone..... 191–193
James, Edwin, on Ozark Mountains, Missouri..... 199
on Black Hills, Dakota..... 214
correlations of..... 396–397
Jenney, W. P., on rocks of Texas..... 218
Johannian, definition of..... 249
Johnston, J. F. W., on rocks of New Brunswick..... 60
Jukes, J. B., on rocks of Newfoundland.. 50, 51
definition of St. John's..... 248
Jukes-Brown, A. J., cited on Tremadoc slates..... 241

K.

Kanab Creek, Arizona, section..... 356
Katemcy, definition of..... 246
Kayser, E., on primordial fossils of South America..... 379
Kelly's Island, Newfoundland, section.... 259
Kerr, W. C., on rocks of North Carolina. 138 139
Kicking Horse Pass, fossils from..... 163, 170
King, Clarence, on rocks of Utah..... 157
comparison of Utah and Welsh rocks. 157
on rocks of Nevada and Utah..... 159 160
correlation by..... 412
King, H., on rocks of Missouri..... 199
correlations by..... 199
Knox sandstone and shale, description of. 301–302
fossils of..... 302–303
Knox sandstone of Alabama..... 306–307
Knox shale of Georgia..... 303
Knox shales of Alabama..... 307
Kootanie Pass, section..... 163

L.

Labrador, Lower Cambrian in..... 274
Lake Superior sandstone, description of. 188–199, 335–339
J. J. Bigsby on..... 188
H. W. Bayfield on..... 188
Douglass Houghton on.....188–190
H. D. Rogers on..... 190

Page.

Lake Superior sandstone—Continued.
D. D. Owen on.....190–191
age of.....190, 191, 192, 194, 197
C. T. Jackson on.....191, 193
Foster and Whitney on.....191–192, 193
J. W. Foster on..... 191
Bela Hubbard on.....191–192
Jules Marcou on..... 192
J. D. Whitney on.....194, 198
H. R. Schoolcraft on..... 194
A. Winchell on..... 194
J. S. Newberry on..... 194
T. S. Hunt on.....195, 197, 198
Charles Whittlesey on..... 195
correlated with St. Croix..... 195
Thomas Macfarlane on..... 195
Alexander Agassiz on..... 196
Brooks and Pumpelly on..... 196
C. Rominger on..... 196
R. D. Irving on.....196, 197, 198, 199
E. T. Sweet on.....196–197
M. E. Wadsworth on.....197, 198
A. R. C. Selwyn on.....197–198
J. D. Whitney on..... 198
N. H. Winchell on..... 198
T. C. Chamberlin on..... 198
M. E. Wadsworth on..... 198
Irving and Chamberlin on..... 199
fossils of..... 228
definition of..... 252
Lake Superior section 336–337
Lane, A. C., on rocks at Nahant, Massachusetts, cited..... 78
Lapham, I. A., on rocks of Wisconsin.... 172
Laramie Mountains, Wyoming, age of Cambrian rocks of..... 212, 350
Laughing White Fish River, Michigan, section..... 337–338
Lea, I., on rocks at Braintree, Massachusetts..... 74
Lesley, J. P., on South Mountain rocks.. 127
on Primal series..... 129–130
atlas of Pennsylvania..... 131
work of, in Tennessee..... 141
on rocks of Pennsylvania..... 288–289
Levis shales described..... 285–286
Lewis, H. C., on primal slates and Potsdam sandstone..... 131
Lingulella lamborni.....200–201, 340, 341
Little Belle Isle, Newfoundland, section. 259
Little, George, on rocks of Georgia..... 145
Llano County, Texas, section..... 355
Logan, W. E., on rocks of Newfoundland. 51
tabulation of Lower Paleozoic rocks. 51, 52
on rocks of Lower St. Lawrence..115, 118–119
on rocks of Quebec..... 116
on Quebec group..... 117
on rocks of Canada..... 207–208
on fossils of Canada.....229–230, 231
on Scolithus linearis..... 280
distribution of Trenton limestone ... 405–406
Logan and Billings, on the rocks of the St. Lawrence River..... 406
Low, A. P., on rocks of Gaspé peninsula.. 120
on rocks of Lake Mistassini..... 122

Page.

Lower Cambrian, divisions of by A. Sedgwick 239
Lower Cambrian fossils in Bristol County, Massachusetts 271–273
Lower Paleozoic rocks, W. E. Logan's tabulation of 51, 52
Lyell, Charles, on Potsdam of New York. 205
Lyman, B. S., on rocks of Virginia 134

M.

Macfarlane, Thomas, on Lake Superior sandstone 195
Maclure, William, on Appalachian rocks 91
correlations of 391–392
classification of rocks 392
Madison sandstone, definition of..... 245, 331
Madison, Wisconsin, section..... 332
Maine, Cambrian rocks of 68–69, 267
Maine and New Hampshire, problems for investigation..... 381
Malade City, Idaho, fossils of 320–321
Manuel's Brook, Newfoundland, section. 52, 260–261, 262, 273
Manitounuck group..... 122
Marcou, J., on Georgia slates 103
on red sandrock 103
on Taconic of Lake Champlain 108
on strata of Taconic system 109, 110
on classification of Taconic system .. 112, 113
on age of Lake Superior sandstone .. 192
proposes Georgia 249
proposes St. Albans 281
Marsh, O. C., on fossil track from Adirondacks 231
Marvine, A. R., on rocks of Arizona..... 220, 221
Maryland, Primal series in 133
Cambrian rocks of 289, 290
Massachusetts (eastern), J. F. and S. L. Dana, on rocks of..... 72
Cambrian rocks of.....72–78, 268–273, 274
M. E. Wadsworth on rocks of..... 76, 77
fossils of..... 88–90
work of C. Dewey in 93, 94
problems for investigation in 381
Mather, W. W., classification of 95
on the rocks of Dutchess county, New York 111
on Potsdam sandstone of New York. 204, 205
Matthew, G. F., rocks of Cape Breton and Newfoundland..... 55
classifications of rocks of New Brunswick 61
on rocks of New Brunswick 62, 64
on rocks of St. John 64, 65
on fauna of Cape Breton 65, 84
on pre-Paradoxides zone at St. John .65, 67, 86
classification of the Cambrian 66, 67
definition of Bretonian 247
definition of St. John 249
definition of Johannian 249
on St. John group 263, 264, 266
classification of rocks in Acadia 265, 266
comparison and correlation of rocks of America and Europe 420, 421

1

Matthew and Bailey, on St. John group..
McConnell, R. G., work of in British Columbia .....
McCreath, A., rocks of Virginia.....
McCutchen, A. R., on rocks of Georgia. 145–14
McGee, W. J., on homogeny in correlation 43
Meade, A. D., section at Stillwater, Minnesota, in well. .....
Meek, F. B., fossils from Antelope Spring, Nevada..... 15
on fossils from Idaho .....
fossils from Utah .....
on rocks of Missouri 20
on fossils in correlation..... 41
Meek and Hayden, on rocks of Black Hills.
fossils from Black Hills.....
Mendota limestone, definition of .....
description of..... 33
Mica-schist series, C. H. Hitchcock on ...
Middle Cambrian in Atlantic Coast province.....
Milne, J., on rocks of Newfoundland.....
Minneapolis, Minnesota, section in well..
Minnesota, D. D. Owen on rocks of.....
Cambrian rocks of 18
N. H. Winchell on rocks of..... 18
general section in .....
Missouri, E. James on rocks of.....
H. King on rocks of .....
G. C. Swallow on rocks of..... 19
Cambrian rocks of 199–201, 33
F. B. Meek on rocks of .....
fossils of.....
G. C. Broadhead on rocks of..... 20
generalized section in 34
problems for investigation in .....
Mistassini Lake, A. P. Low on rocks of...
Montana, Dana and Grinnell on rocks of.
F. V. Hayden on rocks of .....
Cambrian rocks of 162, 163, 32
Montevallo shales, definition of .....
description of.....
Montmorenci Falls, E. Emmons on.....
J. J. Bigsby on.....
Mosquito Range, Colorado, section.....
Moss Agate Springs, Montana, section...
Mount Desert, Maine, C. H. Hitchcock on rocks of .....
N. S. Shaler on rocks of .....
Mount Putnam, Idaho, section 16
Mount Stephen, British America, section.
fossils from 17
Murphy, North Carolina, rocks of..... 13
Murray, Alexander, on rocks of Newfoundland.....
on rocks of Canada.....

N.

Nahant, Massachusetts, A. F. Foerste on rocks of.....
A. C. Lane on rocks at, cited.....
J. H. Sears on fossils from.....
A. F. Foerste on fossils from.....

Page.

Nahant, Massachusetts—Continued.
stratigraphical position of limestone. 271
W. O. Crosby on rocks of. 271
Nason, F. L., on Cambrian of New Jersey 123, 287
Nepigon series. 339
Nevada, G. K. Gilbert on rocks of. 156
E. E. Howell, on rocks in. 156
Arnold Hague on rocks of. 158, 159, 160
Newberry, J. S., on age of Lake Superior sandstone. 194
on rocks of Texas. 218
on rocks of Arizona. 219, 220
New Brunswick, A. Gesner on rocks of. 59
W. B. Rogers on rocks of. 60
J. W. Dawson on rocks of. 60
J. Robb on rocks of. 60
J. F. W. Johnston on rocks of. 60
G. F. Matthew, classification of rocks of. 61
L. W. Bailey on rocks of. 61, 64
G. F. Matthew, on rocks of. 62, 64
Cambrian rocks of. 273, 274
problems for investigation in. 381
New Brunswick and Cape Breton, Cambrian rocks of. 59–67, 262, 267
fossils from. 80–88
C. F. Hartt on. 80
E. Billings on. 80
C. F. Matthews on. 81–88
C. D. Walcott on. 81
New England, C. H. Hitchcock on classification of rocks of. 72
Newfoundland, historical review of work in. 50–55
J. B. Jukes on rocks of. 50, 51
J. W. Salter on Paradoxides from. 50, 78
C. T. Jackson on rocks of. 50
H. W. Bayfield on rocks of. 50
succession of rocks in. 51
W. E. Logan on rocks of. 51
Alexander Murray on rocks of. 52
primordial formations in. 53
J. Howley on rocks of. 53
A. Hyatt on fauna of. 54
J. Milne on rocks of. 54
C. D. Walcott on rocks of. 54, 55, 113
G. F. Matthew on rocks of. 55
fossils from. 78–80
pre-Olenellus beds of. 261
northwestern, Cambrian rocks of. 253–256
southwestern, Cambrian rocks of. 256–256
eastern and southeastern, Cambrian rocks of. 257–262
Cambrian sediments of. 309
problems for investigation in. 380
New Hampshire, Cambrian rocks of 70–72, 267, 268
C. D. Jackson on rocks of. 70
C. H. Hitchcock, classification of rocks of. 70–71
New Jersey, Cambrian rocks of. 122–123, 287
fossils of. 154
problems for investigation in. 382
Newport, Rhode Island, W. B. Rogers on rocks at. 76
Newton, Henry, on rocks of Black Hills. 216

Page.

New York, J. D. Dana on quartzites of eastern. 109
Cambrian sediments of. 311
problems for investigation in. 381
Nicholson, H. A., on life zones. 424–425
Niobrara River, Wyoming, section. 350
Nisconlith series, G. M. Dawson on. 165
Nomenclature of formations. 13
Nomenclature, geologic, general considerations on. 226–237
Nomenclature and classifications, problems of. 383–390
North American Cambrian compared with European. 372–377
North American and European formations, compared. 414–421
North Attleborough, Massachusetts, N. S. Shaler on rocks of. 77
fossils from. 89
North Carolina, Cambrian rocks of. 128–130, 290
problems for investigation in. 383
Northern Appalachian district, definition of. 91, 275
paleontology of. 148–154
distribution of strata of. 275
Cambrian rocks of. 91–122, 275–287
Northern Appalachian Province, sedimentation in. 284
sediments of. 308–309, 312, 313
fauna of. 371
Norwood, J. C., on Lake Superior rocks, cited. 175, 194
Nova Scotia, Cambrian rocks of. 56–59, 262
A. Gesner on rocks of. 56
problems for investigation in. 380
Nova Scotia gold field, J. Campbell on. 57
A. R. C. Selwyn on. 58
H. Y. Hind on. 58
Nova Scotia metamorphic slate, J. W. Dawson on. 57
Nova Scotia gneissoid series, H. Y. Hind on. 58

O.

Obolella pretiosa, range of. 286
Ocoee, definition of. 252
Ocoee conglomerate, description of. 143
Bailey Willis on. 299–300
Ocoee River, rocks of. 141
Olenellus, range of. 319, 370
Olenellus fauna, range of. 280, 281, 310, 362, 386–387, 389
Olenellus gilberti, remarks on. 319, 329
Ophir City, Utah, section. 156, 158, 319–325
Ordway, A., on fossils from Braintree, Massachusetts. 89
Owen, D. D., on rocks of Wisconsin. 171–172, 173–175
on rocks of Minnesota. 181
on rocks of Iowa. 187
on Lake Superior sandstone. 190–191
on fossils of Upper Mississipi valley. 221–222, 223
Owen, Richard, tabulation of rocks. 206

Page.

Owen, R., on fossil footprints of Canada.. 220
Ozark uplift, Missouri..... 199, 201

P.

Paint Rock, North Carolina, rocks at..... 128
Paleontology of Newfoundland 78–80
Paleontology of the Northern Appalachian district..... 148–154
Paleontology of Rocky Mountain Province..... 165–171
Paleontology of Upper Mississippi area.. 221–228
Paleontology of the Adirondack sub-province..... 229–232
Paleontology of the Rocky Mountain sub-province..... 232–234
Paleontology of Arizona..... 235
Peale, A. C., on Gallatin River, Montana. 162–163
on rocks of Idaho..... 161
on rocks of Colorado 209–210
Pennsylvania, Cambrian rocks of. 124–132, 288–289
Pennsylvania, problems for investigation in..... 382–383
Percival, J. G., on Wisconsin, cited..... 175
Perkins, G. H., on Winooski marble..... 110
Perry, J. B., classification of rocks..... 105
on red sandrock 105
Pioche, Nevada, section..... 156
Pogonip ridge, Nevada, section..... 158
Point Levis fossils, E. Billings on..... 116–117
Portland, Maine, C. H. Hitchcock on rocks about..... 68
Portneuf range, Idaho, section..... 321–322
Potsdam, C. H. Hitchcock on Vermont... 105
of Adirondacks, New York..... 113–114
G. H. Cook on New Jersey..... 122–122
F. Prime on Pennsylvania..... 128
d'Invilliers on Pennsylvania..... 130
T. S. Hunt on Pennsylvania..... 132
T. D. Rand on Pennsylvania 132
W. B. Rogers on Virginia 134
J. M. Safford on Tennessee..... 142–143
E. A. Smith on Alabama 147, 306
I. A. Lapham on Wisconsin..... 172
J. Hall on Wisconsin 175–176
Wisconsin, compared with eastern rock 176–177
description of Minnesota, 181, 182, 183, 185, 187
fossils of Minnesota 182, 183
E. Emmons on New York, 202–203, 204, 205, 206
L. Vanuxem on New York..... 204
W. W. Mather on 204, 205
Charles Lyell on..... 205
F. B. Hough on 205 206
J. Hall on New York..... 205
T. S. Hunt on New York..... 206
J. J. Bigsby on New York..... 206
C. D. Walcott on 207
C. E. Hall on..... 207
Beecher and Hall on..... 207
of Wyoming..... 211–212
of Texas.....217, 218, 219
definition of 244
of Newfoundland..... 254
of Wisconsin 332–334

Page.

Potsdam—Continued.
distribution of 341–342
New York, section 342
formations correlated with..... 369
correlations with New York and Mississippi 408–409
Potsdamic, proposed by C. H. Hitchcock.. 252
Powell, J. W., on rocks of Arizona..... 220–221
Primal, definition of..... 251
Primal series, H. D. Rogers on..... 125, 126
geographical distribution..... 126
fossils of 126
equivalents of..... 126
sedimentation of..... 126
shown on sections..... 126–127
F. Prime on..... 128
P. Fraser on..... 129
J. P. Lesley on 129–130
of Maryland 133, 289–290
W. B. Rogers on Virginia 133–134
A. McCreath on Virginia..... 135
W. M. Fontaine on Virginia..... 135–137
of Pennsylvania 289
of Virginia 290–291
Primal slates and Potsdam sandstone, H. C. Lewis on 131
Prime, F., on fossils of Pennsylvania.... 128
on Potsdam of Pennsylvania.....128, 131, 288
on primal slates of Pennsylvania..... 128
Primordial, in Newfoundland..... 53
of Virginia 135, 294–297
definition of..... 243
fauna of Nevada 155
Prospect Mountain, Nevada, section..... 158, 252
Prospect, definition of 159
Prospect Mountain series, fossils of..... 315
description of..... 313, 314
Protozoic, proposed by A. Sedgwick 238
Prout, H. A., on fossils from Potsdam, of Wisconsin 222
Ptychaspis plochensis, range of 170

Q.

Quandary creek, Colorado, fossils of..... 352
Quebec, J. J. Bigsby on rocks near..... 114
Cambrian rocks near..... 285, 287
Cambrian sediments of..... 309–310
R. W. Ells on the rocks of Province of. 120–121
Quebec province, C. D. Walcott on rocks of 121
Quebec gold fields, A. R. C. Selwyn on.... 58
Quebec group, W. E. Logan on..... 116, 117
A. R. C. Selwyn on..... 119
fossils of, in Utah 157–158
rocks of, in Wyoming.....212, 213, 351

R.

Rand, T. D., on Potsdam of Pennsylvania 132
Red sandrock, description of 96–98, 250
J. Marcou on..... 103
J. B. Perry on 105
C. H. Hitchcock on..... 106
J. D. Dana on 107

Page.

Red sandrock—Continued.
distribution of ... 277
character of ... 277
Richardson, J., on rocks of the St. Lawrence River ... 118
Riley, definition of ... 246
Robb, J., on rocks of New Brunswick ... 60
Rockfish Gap, Virginia, section ... 291, 292–293, 294
Rocky Mountain province, problems for investigation in ... 384–385
definition of ... 155, 313
Cambrian rocks of ... 156–165, 313–329
paleontology of ... 165–171
sedimentation of ... 328–329
Rocky Mountain sub-province, paleontology of ... 233–234
definition of ... 347
Cambrian rocks of ... 347–354
Roemer, F., on rocks of Texas ... 216, 217
fossils from Texas ... 234
Rogers, H. D., classification of ... 94–95
on rocks of New Jersey ... 122
correlation of sandstone No. I ... 124
on rocks of Pennsylvania ... 124–127
description of Primal series ... 125–126, 289
on South mountain rocks ... 128
on Lake Superior sandstone ... 190
principles of correlation ... 417–418
Rogers, H. D. and W. B., definition of Primal ... 251
on correlation of rocks ... 403–404
Rogers, W. B., on rocks of New Brunswick ... 60, 61
on rocks at Braintree, Massachusetts. 73, 74
on fossils from Fall River, Massachusetts ... 75
on rocks at Newport, Rhode Island ... 76
on fossils from eastern Massachusetts. 88
on Primal series of Virginia ... 133–134, 290–291
sections in Virginia ... 136
Rogers, W. B. and H. D., on lithologic character in correlation ... 428
Rome sandstone, definition of ... 247
Rominger, C., on Lake Superior sandstone 196, 337
Rosenfield station, Canada, section ... 334

S.

Safford, J. M., classification of rocks in Tennessee ... 141–142, 144
metamorphic rocks of eastern Tennessee ... 142
Potsdam group of Tennessee ... 142–143
fossils of Tennessee ... 154
definition of Chilhowee ... 251
definition of Ocoee ... 252
on rocks of Tennessee ... 300–302
on classification of rocks ... 405
Saint Albans, proposed by J. Marcou ... 281
Saint Croix, N. H Winchell on Minnesota. 182, 183, 186
definition of ... 245
description of ... 330–334
Saint Croix district, Wisconsin, section ... 333–334
Saint John, New Brunswick, work of J. W. Dawson on rocks at ... 61

Page.

Saint John, New Brunswick—Continued.
G. F. Matthew on rocks of ... 64–65
G. F. Matthew on pre-Paradoxides zone at ... 65, 67, 86
pre-Paradoxides, beds of ... 264–265
C. D. Walcott, on fossils from ... 81
A. Hyatt, on fossils from ... 82
Saint John group, C. F. Hartt on ... 62
Matthew and Bailey on ... 62
C. D. Walcott on ... 65
definition of ... 249
description of ... 263–264
divisions of ... 265
Saint John, O., on rocks of Idaho ... 161
on rocks of Wyoming ... 213, 214, 350–351
Saint John's slate, description of ... 50, 51
J. F. Whiteaves on ... 54
definition of ... 248
Saint Lawrence River, W. E. Logan, rocks on ... 115, 118–119
J. J. Bigsby on rocks of ... 116
J. Richardson on rocks of ... 118
Saint Louis, Missouri, section in well ... 200, 340
Saint Peter's sandstone and Chazy limestone compared ... 176–177
Salem Village, New York, section ... 282–283
Salt Range, India, section ... 378
Salter, J. W., on Paradoxides from Newfoundland ... 50
fossils of Georgia ... 155
on Tremadoc slates ... 241
Salter and Aveline on Caradoc ... 239
Saratoga, New York, section ... 346
Saratoga section compared with other sections ... 346
Saratoga County, New York, J. H. Steele on rocks of ... 201–202
Sardinia, Cambrian rocks of island of ... 375
Scandinavia, Cambrian rocks of ... 375
Schell Creek Mountain, Nevada, fossils of. 158
Schoolcraft, H. R., on age of Lake Superior sandstone ... 194
Scolithus linearis. 131, 132, 137, 147, 172, 306, 404, 407
Scotland, Cambrian rocks of ... 376
Sears, J. H., on fossils from Nahant, Mass. 78
Secret Cañon shale, definition of ... 248
description of ... 315
fauna of ... 315
Sedgwick, A., on Upper Cambrian ... 237–238, 239
on Middle Cambrian ... 238, 239
on Lower Cambrian ... 238, 239
Selkirk, British Columbia, section ... 165
Selwyn, A. R. C., gold field of Quebec and Nova Scotia ... 58
on Cambrian group ... 119
on the Quebec group ... 119
on Lake Superior sandstone ... 197–198
on volcanic portion of Cambrian ... 286–287
Shaler, N. S., on rocks of Mount Desert, Maine ... 69
on rocks at Braintree, Massachusetts. 75
on geology of Bristol County, Massachusetts ... 77, 271–272
Shaler and Foerste, on fossils of eastern Massachusetts ... 89–90

Page.

Shaler and Williams on rocks of Little Falls, New York 207, 347
Shumard, B. F., on Wisconsin, cited 185
on rocks of Texas 217
fossils from Wisconsin and Missouri. 223
fossils from Texas 234–235
Signal Hill sandstone, description of 50, 51, 52
Sillery series, position of 286
Sioux quartzite, description of 182, 185
fossils from 185
age of 184–185
Smith, E. A., work of, in Alabama 146–148
on metamorphic rocks of Alabama ... 146–147
on classification of rocks of Alabama. 147
on Potsdam sandstone of Alabama ... 147
definition of Montevallo 247
definition of Coosa 247
definition of Weisner 251
on rocks of Alabama 305–308
Smock, J. C., on the rocks of Dutchess County, New York 111
Snowden slate quarries, Virginia, section. 297
South America, Cambrian rocks of 379
South Mountain, Pennsylvania, H. D. Rogers on sandstone of 124, 125, 128
J. P. Lesley on 127
P. Frazer on 128
Southern Appalachian district, definition of 122, 287
Cambrian rocks of 122–148, 287–308
paleontology of 154–155
Southwestern sub-province, definition of. 216, 354
Cambrian rocks of 216–221, 354–357
sediments of 357–358
Spring Creek, Dakota, section 348
Stevenson, J. J., on rocks of Virginia .. 137, 298–299
Steele, J. A., on rocks of Saratoga County, New York 201–202
on fossils of Adirondacks 229
Straits of Belle Isle, Newfoundland, rocks of 254
Strong, Moses, on rocks of Wisconsin 180
Sutton Mountain anticlinal, Canada 286
Swallow, G. C., on rocks of Missouri 199–200
Swanton, Vermont, section 103, 279–280
Sweet, E. T., on rocks of Wisconsin, cited 178
on Lake Superior sandstone 196, 197, 337

T.

Taconian, definition of 243
Taconian system, pre-Cambrian 132
Taconic slate, A. Fitch on 98–99
C. B. Adams on 99
Taconic group in Minnesota 185
Taconic system, E. Emmons on 98
J. Marcou on Lake Champlain 108
J. Marcou on 109–110
J. Marcou classification of 112–113
definition of 242–243
Tennessee, G. Troost on rocks in 139–141
Cambrian rocks of 139–144, 299–303
work of J. P. Lesley on rocks of 141
J. M. Safford's classification of rocks of 141–142, 144

Page.

Tennessee—Continued.
J. B. Elliott on rocks of 144
Cambrian fauna of 154–155
Cambrian sediments of 311
problems for investigations in 383
Texas, F. Roemer, on rocks of 216, 217
Cambrian rocks of 216–219, 354–356
B. F. Shumard on rocks of 217
S. B. Buckley on rocks of 218
C. D. Walcott on rocks of 218
T. B. Comstock on rocks of 219
W. P. Jenney on rocks of 218
J. S. Newberry on rocks of 218
paleontology of 234–235
Cambrian sections of, compared with others 355
division of rocks by T. B. Comstock .. 355–356
problems for investigation in 385
Thompson, Z., on red sandrock 97
Timpahute range, Nevada, section 156
Tonto group, description of 220, 221
Tonto sandstone, definition of 245
description of 357
Topsail Head, Newfoundland, section 52
fossils of 55, 260
Toughkenamon division 130
Toumey, M., on rocks of Alabama 146
Tremadoc slates 241–242, 374
Trenton limestone, distribution of 405–406
Trinity Bay, Newfoundland, section 53
Troost, Gerard, classification of rocks 139
on rocks of Tennessee 139–141
on Cambrian system of Tennessee. 140–141, 240
Trout Creek, Colorado, section 209–210, 353
Troy, N. Y., S. W. Ford on rocks at 106
J. Hall on fossils from 99
Tyson, P., on rocks of Maryland 289–290

U.

Upper Cambrian in Atlantic Coast province 274
Upper Mississippi area, definition of 171
Cambrian rocks of 171–199
paleontology of 221–228
Upper Mississippi Valley, Cambrian rocks of 330–334
problems for investigation in 385
Upham, Warren on rocks of Minnesota, cited 186
Utah, F. H. Bradley on rocks of 156, 157
Clarence King on rocks of 157
S. F. Emmons on rocks of 157–158
Cambrian rocks of 319–320
Utah and Nevada, Cambrian rocks of 155–160, 312–320
fossils from 169, 170
problems for investigation in 384

V.

Vanuxem, Lardner, on Potsdam sandstone of New York 204, 205
Vermont, C. B. Adams on quartz rock of . 95
C. H. Hitchcock on quartz rock of 96
Amos Eaton on rocks of 98

Page.

Vermont—Continued.
C. H. Hitchcock on fossils from 99
J. Hall on fossils of 100, 102
formations of, C. H. Hitchcock on.... 104
T. S. Hunt on geology of 104
C. H. Hitchcock on Potsdam in..... 105
A. Wing's discoveries in..... 107
Cambrian rocks of..... 107
J. E. Wolff on fossils of..... 113
T. N. Dale on rocks of..... 283
Cambrian sediments of..... 310–311
problems for investigation in..... 381–382
Verneuil, Edward de, principles of correlations 414–415
Virginia, Cambrian rocks of 133–138, 290–299
B. S. Lyman on rocks of..... 134
A. McCreath on rocks of 135
J. L. and H. D. Campbell on rocks in.. 136
H. D. Campbell on rocks of..... 137
J. J. Stevenson on rocks of..... 137, 298–299
W. M. Fontaine on rocks of 291, 292–297
Cambrian sediments of 311
problems for investigation in 383

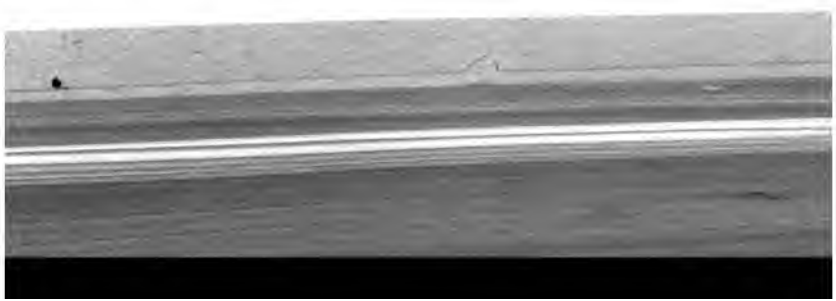
W.

Waagen, W., on fauna of India..... 378
Wadsworth, M. E., on rocks of eastern Massachusetts..... 76, 77
Lake Superior sandstone 197, 198
on Braintree quarry 271
Walcott, C. D., on rocks of Newfoundland 54–55, 113
on St. John group..... 65
classification of the Cambrian.....66, 77, 113
on fossils from Braintree..... 89
on the Cambrian of Georgia, Vermont 110
on the rocks of Washington County, New York..... 112
on granular quartz..... 112
on rocks of Province of Quebec..... 121
correlation of rocks in Tennessee.... 144
fossils from Georgia slates..... 151–152
fossils of Lower Cambrian 153–154
fossils from Alabama 155
on fossils of Utah..... 158, 166
fossils of Nevada 160, 167–170
on fossils from British Columbia 163–164
on Potsdam of New York..... 207
on rocks of Texas 218
on rocks of Arizona 221
fossils from Wisconsin and Minnesota..... 228
on fossils from Saratoga County, New York 231–232, 232–233
fossils from Black Hills..... 234
fossils from Texas 235
principles of correlation 413
Wales, Cambrian rocks of 373–374
Wasatch Mountains, Utah, section..... 157
sedimentation of..... 328
Washington, Iowa, section in well 188
Washington County, New York, section in..... 281–283

Page.

Waterville, Maine, C. H. Hitchcock on fossils of..... 101
Waverly gold district, Nova Scotia, H. Y. Hind on..... 57
Weber Cañon, Utah, section 158
Webster, J. W., on rocks of Boston and vicinity 72
Weisner quartzite, definition of..... 251
description of..... 308
Weisner, Georgia, section..... 304–305
Western border or Rocky Mountain subprovince, definition of 209
Cambrian rocks of..... 209–216
Western sandstone, description of....197, 335–336
definition of..... 252
White, C. A., fossils of Utah 166
classification of rocks of Iowa..... 187
on fossils of Arizona..... 220–221
White, George, on rocks of Georgia 144–145
Whiteaves, J. F., on slates of St. John's.. 54
Whitehall, New York, section..... 344–345
Whitfield, R. P., on fossils from Braintree, Massachusetts 89
correlations of 108–109
fossils of northern Vermont 151
on fossils from Black Hills.....216, 233 234
fossils of Wisconsin..... 226–227
Whitney, J. D., fossils from Nevada..... 155, 165
on Lake Superior sandstone 194, 198
principles of correlation 411
Whitney and Wadsworth on copper-bearing rocks, cited..... 198–199
Whittlesey, C., on rocks of Wisconsin . . 172–173
on Lake Superior sandstone..... 195
William's Cañon, Colorado, section 352
Williams, H. S., on life history in correlation, cited 426
Willis, Bailey, on Ocoee of Tennessee.. . 219 300
Winchell, A., on rocks of Wisconsin..... 178
on Lake Superior sandstone..... 194
fossils from Wisconsin..... 225 226
Winchell, N. H., correlations of.. 109, 184, 186, 187, 207, 409 410
on rocks of Minnesota..... 181, 187
section at Emmettsburg, Iowa..... 187
on rocks of Black Hills 216
fossils from St. Croix sandstone 228
definition of St. Croix 245
on lithologic character in correlation. 428 429
Wind River range, Wyoming, rocks of ... 350
Wing, A., discoveries in Vermont..... 107
Winooski marble, E. Billings on..... 103–104
C. H. Hitchcock on 105
G. H. Perkins on..... 110
Winwood, H. H., on fossils from Kicking Horse Pass..... 163
Wisconsin, Cambrian rocks of..... 171 181
D. D. Owen on rocks of.....171–172, 173–175
I. A. Lapham on rocks of..... 172
Charles Whittlesey on rocks of..... 172–173
J. Hall on rocks of.....173, 175–178
geologic map of..... 178
work of R. D. Irving in..... 178
A. Winchell on rocks of..... 179
T. C. Chamberlin on rocks in..... 179–180

	Page.
Wisconsin—Continued.	
L. C. Wooster on rocks of	179–180
Moses Strong on rocks of	180
succession of beds of Potsdam in	331
Wolff, J. E., on fossils from Vermont	113
on limestones of East Rutland Valley, Vermont	276
Woodward, H., on trilobites of Australia	379
Woodward, John, correlations of	391
Wooster, L. C., on Potsdam sandstone	179–180
Wyoming, F. V. Hayden on rocks of	211–212
Cambrian rocks of	211-214, 349–351
A. Hague on rocks of	212
F. H. Bradley on rocks of	212
T. B. Comstock on rocks of	212–213
F. M. Endlich on rocks of	213
O. St. John on rocks of	213, 214
Y.	
Young, A. A., on Potsdam sandstone, cited	180



Stanford University Libraries
3 6105 022 529 395